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A COMPREHENSIVE COMPUTER PROGRAM FOR PREDICTING SOLAR CELL PERFORMANCE

by J. P. Kirkpatrick, C. A. Lewis, and J. C. Gaspar

Ames Research Center
Moffett Field, Calif. 94035

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16. Abstract

A comprehensive computer program has been developed to predict the performance of solar cells and complete arrays as a function of solar intensity. The program is unique in its capability to calculate the light-generated current of a single cell by integrating the solar or simulator spectrum with the following parameters as a function of wavelength: solar cell spectral response, filter transmission, and space radiation damage. (Variations with temperature and incidence angle can also be handled.) The diode equation is then used to obtain the current-voltage characteristics and maximum power point. The prediction accuracy is enhanced over a wide range of light intensities by using a variable curve factor derived from experimental data in the diode equation. Array current-voltage curves may be calculated for combinations of series and parallel cell wiring arrangements. These curves reflect wiring and diode losses as well as angular orientation to the sun.

The program is also useful in extrapolating available data, comparing experimental data taken with different energy sources, and correlating experimental and analytical predictions.

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SUMMARY

A comprehensive computer program has been developed to predict the performance of individual solar cells and complete arrays as a function of solar intensity. The program is unique in its capability to calculate the light-generated current of a single cell by integrating the solar or simulator spectrum with the following parameters as a function of wavelength: solar cell spectral response, filter transmission, and space radiation damage. (Variations with temperature and incidence angle can also be handled.) The diode equation is then used to obtain the current-voltage characteristics and maximum power point. Using a variable curve factor derived from experimental data in the diode equation enhances the prediction accuracy over a wide range of light intensities. Array current-voltage curves may be calculated for combinations of series and parallel cell wiring arrangements. These curves reflect wiring and diode losses as well as angular orientation to the sun.

The program is also useful in extrapolating available data, comparing experimental data taken with different energy sources, and correlating experimental and analytical predictions.

INTRODUCTION

Optimization of solar array design and performance prediction for future missions is becoming more complex as spacecraft encounter wider variations in the solar environment and extended exposures to damaging space radiation. The use of thermal control techniques to provide satisfactory cell temperatures may also introduce variables that must be considered. For example, a parametric study of solar array performance for a near solar mission may require that coverglass-filter transmission, solar cell response, and space radiation damage be considered on a wavelength basis as a function of solar distance, angle of solar incidence, and cell temperature. Correlation of data obtained with different energy sources also requires spectral calculations.

The program described, unlike current programs (refs. 1-4), is capable of predicting cell performance over a wide range of light intensities using spectral information directly. It is written in Fortran and is operational on both the IBM 7040/7094 Direct Couple System (DCS) and the IBM 360/67 computers with optional graphic output on an S-C 4020.

To provide maximum utility, the program calculates individual cell or total array performance on the basis of either a few basic cell parameters or detailed spectral data which may be a function of one, two, or three independent variables. A modification of the classical diode equation (ref. 5) is used to construct the current-voltage curve from which maximum power is determined. A variable

curve factor derived from experimental data is used to enhance the accuracy of the diode equation in predicting the shape of the current-voltage curve at high light intensities.

Total array performance is synthesized by combining single cells into parallel and series wiring configurations to form strings and then accounting for the total number and solar orientation of each string in the array.

SOLAR CELL MODEL

Current Density

Incident light energy is converted by a solar cell into electrical current. The short circuit current density is the current flow per unit of cell area developed at the terminals when the external load has zero resistance. It is determined from the following expression:

$$\mathrm{JCD} = \frac{140 \cos \mathrm{THETA}}{\mathrm{AU}^2} \{\mathrm{XJLTR}[1 + \mathrm{ATX}(\mathrm{T} - \mathrm{TREF})]\} \tag{1}$$

where

JCD short circuit current density, mA/cm^2

THETA angle between the solar vector and the normal to the cell surface, deg

AU solar distance, AU

XJLTR conversion constant at reference conditions, mA/mW of incident energy

ATX temperature coefficient defined as the dimensionless change in current per °K change in temperature. When XJLTR is calculated by method 2 (discussed below), ATX is for the bare cell when filtered coverglasses are being considered.

T cell operating temperature, °K

TREF reference temperature for standard test conditions, typically taken as 301° K

Equation (1) states that the maximum current density is determined by the product of the normal component of the incident light energy and the power-to-current conversion constant as modified by the deviation in temperature from reference conditions.

The temperature coefficient is usually provided by the cell manufacturer either directly or in curve form. The conversion constant, however, may not be available, and under such circumstances the computer program will calculate this factor by one of two different methods. The first requires a measurement of short circuit current (IREF) under standard text conditions (i.e., light intensity = 140 mW/cm^2 at temperature TREF). This is usually available from the manufacturer. The computer solves the equation

$$XJLTR = \frac{IREF}{AREA \times 140} \tag{2}$$

where AREA is that of the solar cell. XJLTR is then considered a constant that does not change as parameters deviate from standard test conditions. At large angles of incidence and temperature extremes, this assumption may be invalid as a result of changes in coverglass-filter transmission and cell spectral response. The second method is suggested for calculating XJLTR under these conditions.

The second method constitutes a unique feature of this computer program and evaluates XJLTR by integrating on a wavelength basis the incident energy, the solar cell response, and the filter-coverglass transmission (if used). Both the transmission and response characteristics may be degraded for space radiation damage. This integration is performed by the following operation:

$$XJLTR = CONST \sum_{0.3}^{1.3} \{L_\lambda [R_\lambda(THETA,T) - \Delta R_\lambda(AU,THETA)] [TR_\lambda(THETA,T) - \Delta TR_\lambda(AU,THETA)]\} \tag{3}$$

where

L_λ (LSOLAR) relative spectral energy distribution of the light source expressed as a ratio of energy in each wavelength interval (usually 0.01 μ) to the total energy (This information is interpolated from tables LSOLAR(L_λ) and WAVE(wavelength), defined by data statements in subroutine RESPE. These tables are of length NW. The wavelength values in this statement are used as the discrete summation points in the numerical integration.)

R_λ (RESP) relative spectral response of the solar cell in dimensionless units in the form of an interpolated table with values of RESP as a function of wavelength; or wavelength and incidence angle; or wavelength, incidence angle, and temperature

TR_λ (TRANS) spectral transmission expressed as a ratio of transmitted to incident light for the coverglass-filter assembly, in the form of an interpolated table with values of TRANS as a function of wavelength; wavelength and incidence angle; or wavelength, incidence angle, and temperature (For bare cells, this table may be eliminated and TRANS is automatically set equal to unity.)

ΔR_λ (DRESP) degradation in cell response caused by space radiation from the undegraded values listed in the response tables, in the form of an interpolated table with values of DRESP as a function of wavelength; wavelength and incidence angle; or wavelength, incidence angle, and AU (position in orbit)

ΔTR_λ (DTRANS) degradation in coverglass-filter transmission caused by space radiation from the undegraded values listed in the transmission tables, in the form of an interpolated table with values of DTRANS as a function of wavelength; wavelength and incidence angle; or wavelength, incidence angle, and AU (position in orbit)

CONST proportionality factor that converts the relative cell response used by the numerical integration to absolute units of mA/mW. Its value may be input directly or calculated by the program from the following equation:

$$\text{CONST} = \frac{\text{IREF}}{\text{AREA} \times \text{TIRR}} \frac{1}{\sum_{\lambda}[(\text{LREF}_{\lambda})(\text{R}_{\lambda})]} \tag{4}$$

where

IREF short circuit current in mA at reference conditions (TREF, LREF, TIRR). This is normally at air mass zero (amz).

LREF_{λ} (LREF) relative spectral energy distribution of the source used to obtain IREF (Johnson's solar spectrum (ref. 6) is used by the program, but is easily replaced if the associated amz short circuit current is not available. LREF_{λ} is defined in subroutine RESPE by data statement LREF, the values of which correspond to center wavelengths defined by data statement RWAVE. The tables are of length NP.)

AREA cell area, cm^2

TIRR total irradiance of source used to obtain IREF in mW/cm^2

R_{λ} (RESP) relative spectral response of solar cell at TREF and zero angle of incidence

Once XJLTR has been determined and equation (1) solved, the light-generated current (IL) is obtained by the product of the current density (JCD) and the cell area, that is,

$$\text{IL} = \text{JCD} \times \text{AREA}$$

XJLTR is the dominant parameter affecting the value of JCD and an uncertainty in its magnitude should be reflected in IL. ATX, however, is generally less than 0.001 and becomes important only for large deviations from the reference temperature.

Open Circuit Voltage

The open circuit voltage (VOC) is determined from the following expression:

$$\text{VOC} = \text{VREF} - \text{BRS}(\text{T} - \text{TREF}) + \text{VCL}(\text{IL} - \text{IREF}) \tag{5}$$

where

VREF open circuit voltage under standard test conditions, mV

BRS voltage-temperature coefficient defined as the change in voltage per degree change in temperature, mV/°K

VCL voltage-light intensity coefficient defined as the change in voltage per change in light-generated current from standard reference conditions, mV/mA

T, TREF, IL, and IREF are as previously defined.

The voltage-temperature coefficient (BRS) is an important parameter and is generally available from the manufacturer. The voltage-light intensity coefficient (VCL) is derived from experimental data and becomes significant only for large variations in light intensity. Typical values of VCL are included in the sample problems.

Basic Diode Equation

The program uses the classical diode equation for a solar cell to generate current-voltage (I-V) curves for specific operating conditions. This equation may be written as:

$$I = IO \left\{ \exp\left[\frac{q(V - I \cdot RS)}{1000\ A \times K \times T} \right] - 1 \right\} - IL \tag{6}$$

where

I load current, mA

IO reverse saturation current, mA

V load voltage, mV

RS series resistance, Ω

IL light-generated current, mA

A factor used to fit experimental curve to theoretical curve

K Boltzmann's constant, $1.38\text{X}10^{-23}$ J/°K

T temperature, °K

q electronic charge, $1.60\text{X}10^{-19}$ coulombs

The above expression is based on the generally applied, single-stage equivalent circuit for a solar cell. To improve prediction accuracy over a wide range of light intensities, a variable curve factor A derived from experimental data is employed. The optimum A factor as a function of light intensity is depicted in figure 1 and has been found to yield accuracies within 3 percent at the maximum power point for cells of various manufacturers tested at solar intensities up to 25 solar constants. If accurate predictions are required at high light intensities without a variable curve factor, it would be necessary to use a more complicated model for the solar cell utilizing distributed

parameters for a more realistic representation of the circuit operation. This, in turn, would result in a complex mathematical expression for the current-voltage relationship requiring basic cell information not readily available.

The series resistance (RS) should be available from the cell manufacturer, but may be computed by the measurement technique of Wolf and Rauschenbach (ref. 5) if necessary.

The standard reverse current for a diode, IO, is determined from a solution of the diode equation under open circuit conditions. This gives the following:

$$IO = \frac{IL}{\exp\left(\frac{qVOC}{1000\ A \times K \times T} - 1\right)} \tag{7}$$

The computer program first solves equation (5) to obtain VOC. Then IO is determined by equation (7). Incremental values of V are then used in equation (6) to generate an I-V curve. The maximum power point is then computed from these data.

ARRAY CALCULATIONS

Performance may be calculated for solar arrays that are either sun-oriented or spinning and composed of a single flat paddle or a complex combination of panels with different angular orientations to the sun.

The string current-voltage (I-V) characteristic is first determined at each desired angular orientation (THETA) by multiplying the current coordinate (for a series of incremental voltages) of the individual cell I-V curve by the number of cells connected in parallel (NIS) and the voltage coordinate by the number of cells in series (VIS). The voltage coordinate thus obtained is then reduced by the string circuit loss (SCL). Algebraically, this may be represented by

$$I(i)_{string} = NIS \times I(i)_{cell} \tag{8}$$

$$V(i)_{string} = VIS \times V(i)_{cell} - SCL \tag{9}$$

where (i) varies in steps from zero to the single-cell open circuit voltage (VOC).

The current coordinates of the string I-V curves are next multiplied by the number of strings (FTHETA) at each angular orientation of the sun, and the current contributions at each angle are then summed to obtain the final shape of the array I-V curve. String and array voltage coordinates are assumed to be identical. These operations may be represented by

$$I(i)_{array} = \sum_{THETA} \left[I(i)_{string} \times FTHETA \right] \tag{10}$$

$$V(i)_{array} = V(i)_{string} \tag{11}$$

where (i) varies as before.

The maximum power output of the solar array is then determined from the array I-V curve.

PROGRAM FLEXIBILITY

The program accepts input information ranging from single-valued coefficients to complex trivariant tables. It can predict the performance of a single cell or a multifaced array throughout an entire mission. Characteristic of the varied tasks performed by the program are the following calculations that appear in detail as sample problems in appendix A.

1. Single-cell current-voltage curve and maximum power point determined from a minimum of cell parameters with graphical output of power versus voltage and current versus voltage

2. Array I-V characteristics and maximum power point for a cylindrical array with its spin axis normal to the ecliptic plane

3. Filtered cell output calculated from coverglass-filter transmission and cell response input as a function of wavelength

4. Performance of a filtered cell during laboratory tests using simulated solar radiation

5. Complete array calculations, including space radiation damage, for a spinning spacecraft with solar panels inclined at an angle to the solar vector. The cell response is a function of wavelength and incidence angle, and the coverglass-filter transmission is a function of wavelength, incidence angle, and temperature.

In addition to the mission-oriented applications described above, the program is also well suited to basic studies of various cell parameters such as series resistance, temperature coefficients, and spectral response.

CONCLUDING REMARKS

Basic cell and total array performance can be predicted for a wide range of environmental conditions using known coefficients and either test data taken under standard reference conditions

or spectral information on cell response, light source, and (if desired) coverglass-filter transmission and space radiation damage. The accuracy of computed I-V curves and maximum power points is commensurate with the accuracy of the input data.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., 94035, Apr. 1, 1970

APPENDIX A

SAMPLE PROBLEMS

SAMPLE PROBLEM 1 – SINGLE-CELL CALCULATION

A particular low-series resistance solar cell is being considered for a Mercury mission. The output characteristics of this cell at 0.50 AU, normal incidence, and a panel temperature of 360° K are desired. The following data are available from the manufacturer's information and laboratory tests:

IREF 60 mA (short circuit current at 1 solar constant)

VREF 594 mV (Open circuit voltage at 1 solar constant)

TREF 303° K

RS 0.11 (cell series resistance)

Light intensity, sun	Temperature (T), °K	Current (I), mA	Voltage (V), mV
1	303	60.0	594
1	393	61.8	397
6	393	376	464

The coefficients ATX, BRS, and VCL may be calculated from these data as follows:

$$\text{ATX} = \frac{I_2 - I_1}{I_1}\,\frac{1}{T_2 - T_1} = \frac{61.8 - 60.0}{60.0}\,\frac{1}{393 - 303} = 0.00035/°\text{K}$$

$$\text{BRS} = \frac{V_1 - V_2}{T_2 - T_1} = \frac{594 - 397}{393 - 303} = 2.0 \text{ mV/°K}$$

$$\text{VCL} = \frac{V_3 - V_2}{I_3 - I_2} = \frac{464.0 - 397.0}{376.0 - 61.8} = 0.21 \text{ mV/mA}$$

Figure 1 indicates a value of 1.43 for A. Detailed output and plotting are desired, but radiation damage is not to be considered.

The input data form, data deck listing, and computer output are shown in figures 2, 3, and 4; current-voltage and power-voltage curves are plotted in figures 5 and 6.

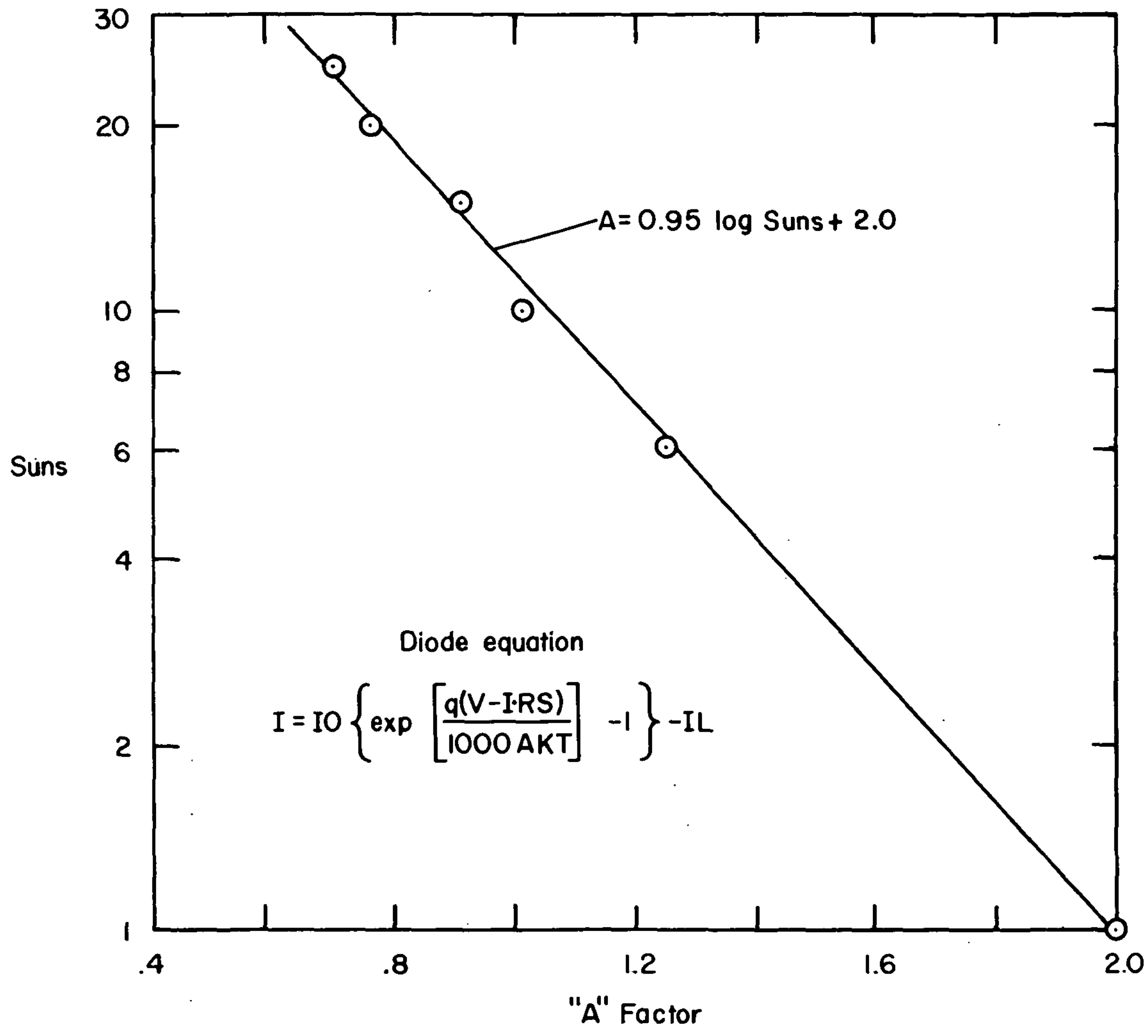


Figure 1.- Variation in "A" factor with intensity.

INPUT DATA - SOLAR CELL PERFORMANCE PROGRAM

FORMAT INPUT DATA

A6 RUN 1

12A6 TITLE CARD Sample Problem 1 - Single-Cell Calculation

8I10 NAU 1 NTHETA 1 KPLOT 1 KOUT 1 INT 0 INR 0 INTD 0 INRD 0

8F10.4 AU 0.50

TEMP 360.

A 1.43

VCL 0.21

AREA 2.0 TREF 303. VREF 594. IREF 60.0 XJLTR 0. ATX .00035

BRS 2.0 RS 0.11

THETA 0.

FTHETA 1.

NIS 0. VIS ______ SCL ______

PLOT CARD 08/30/68 KIRKPA AMES 244

TABLES

TRANSMISSION (TRANS) Not used - delete

RESPONSE (RESP) Not used - delete

TRANSMISSION DAMAGE (DTRANS) Not used - delete

RESPONSE DAMAGE (DRESP) Not used - delete

COMMENTS Single-cell calculation with a minimum of required input information

Figure 2.- Input data form - Sample Problem 1

```
RUN 1
              SAMPLE PROBLEM 1 - SINGLE CELL CALCULATION
       1          1          1          1          0          0          0          0
     .50
    360.
    1.43
    0.21
     2.0       303.       594.       60.0         0.     .00035         2.        .11
      0.
      1.
      0.
          09/16/69    J GASPAR AMES  233
```

Figure 3.- Data deck listing - Sample Problem 1.

```
 INPUT DATA     RUN 1                   SAMPLE PROBLEM 1 - SINGLE CELL CALCULATION


           NAU=  1
        NTHETA=  1
         KPLOT=  1
          KOUT=  1
          AREA= 0.20000000E 01
          TREF= 0.30300000E 03
          VREF= 0.59400000E 03
          IREF= 0.60000000E 02
         XJLTR= 0.0
           ATX= 0.34999987E-03
           BRS= 0.20000000E 01
            RS= 0.10999995E 00
```

Figure 4.- Output - Sample Problem 1.

12/01/69

SOLAR CELL PERFORMANCE
RUN 1

SAMPLE PROBLEM 1 - SINGLE CELL CALCULATION

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=60.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (SINGLE CELL)

AU= 0.50 THETA = 0.0 TC =360.0 JLTR = 0.21428567E 00 VCL =0.21
IL = 0.24478790E 03 IO = 0.20621119E-02 VOC = 0.51880542E 03 A = 1.43

I	CURRENT(MA)	VOLTAGE(MV)
1	0.24478790E 03	0.0
2	0.24478790E 03	0.10000000E 02
3	0.24478790E 03	0.20000000E 02
4	0.24478790E 03	0.30000000E 02
5	0.24478790E 03	0.40000000E 02
6	0.24478790E 03	0.50000000E 02
7	0.24477534E 03	0.60000000E 02
8	0.24477534E 03	0.70000000E 02
9	0.24477534E 03	0.80000000E 02
10	0.24476125E 03	0.90000000E 02
11	0.24475401E 03	0.10000000E 03
12	0.24475314E 03	0.11000000E 03
13	0.24473355E 03	0.12000000E 03
14	0.24471930E 03	0.13000000E 03
15	0.24471017E 03	0.14000000E 03
16	0.24467911E 03	0.15000000E 03
17	0.24465112E 03	0.16000000E 03
18	0.24462579E 03	0.17000000E 03
19	0.24457216E 03	0.18000000E 03
20	0.24451720E 03	0.19000000E 03
21	0.24444833E 03	0.20000000E 03
22	0.24436487E 03	0.21000000E 03
23	0.24425423E 03	0.22000000E 03
24	0.24411565E 03	0.23000000E 03
25	0.24394846E 03	0.24000000E 03
26	0.24373842E 03	0.25000000E 03
27	0.24347366E 03	0.26000000E 03
28	0.24314253E 03	0.27000000E 03
29	0.24272852E 03	0.28000000E 03
30	0.24221111E 03	0.29000000E 03
31	0.24156488E 03	0.30000000E 03
32	0.24075830E 03	0.31000000E 03
33	0.23975249E 03	0.32000000E 03
34	0.23849962E 03	0.33000000E 03
35	0.23694106E 03	0.34000000E 03
36	0.23500552E 03	0.35000000E 03
37	0.23260670E 03	0.36000000E 03
38	0.22964098E 03	0.37000000E 03
39	0.22598561E 03	0.38000000E 03
40	0.22149620E 03	0.39000000E 03
41	0.21600662E 03	0.40000000E 03
42	0.20932799E 03	0.41000000E 03
43	0.20125087E 03	0.42000000E 03
44	0.19154869E 03	0.43000000E 03
45	0.17998454E 03	0.44000000E 03
46	0.16631828E 03	0.45000000E 03
47	0.15031766E 03	0.46000000E 03
48	0.13176140E 03	0.47000000E 03
49	0.11048154E 03	0.48000000E 03
50	0.86327515E 02	0.49000000E 03
51	0.59201401E 02	0.50000000E 03
52	0.29058151E 02	0.51000000E 03
53	0.0	0.51880542E 03

I(PMAX) = 0.21871051E 03 V(PMAX) = 0.39534399E 03 P(MAX) = 0.86467926E 02

Figure 4.- Concluded.

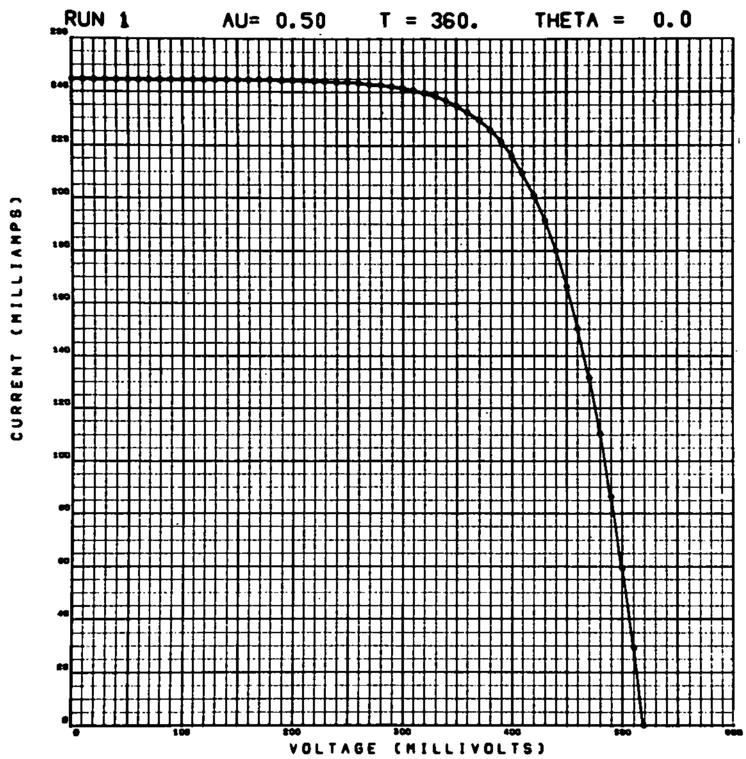


Figure 5.- Current-voltage plot (S-C 4020).

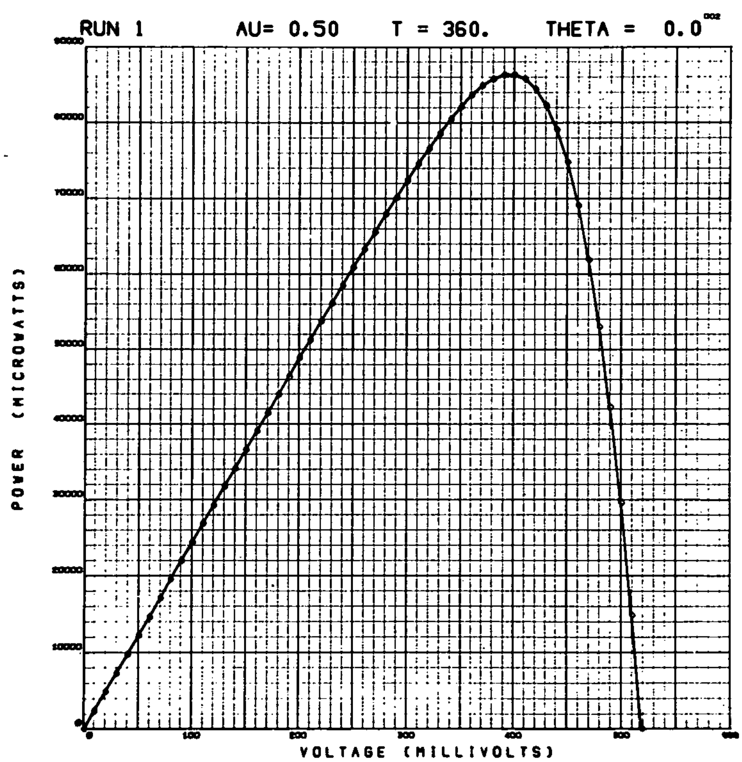


Figure 6.- Power-voltage plot (S-C 4020).

SAMPLE PROBLEM 2 – ARRAY CALCULATION

The electrical output of a solar array operating at 0.5 AU and 363° K is of interest. The cells are similar to the one described in Sample Problem 1 and their characteristics are assumed to be independent of temperature and solar incidence angle. The array is a spinning cylinder with its spin axis normal to the solar vector as shown in figure 7. For convenience, the panels may be considered to be a 36-sided polygon with surface normals at angles with the solar vector of 5°, 15°, 25°, etc. Only half the array is exposed to the sun at any given moment and this half will be symmetrical about the solar vector.

There will be a total of 48 strings, each composed of 4 cells connected in parallel and 54 of these parallel groups connected in series. The circuit loss for each string is estimated to be 0.5 V. For each segment, there will be 48/36 = 1.333 strings. Twice this number of active strings may be considered at each angle from 5° to 85° because of quadrant symmetry.

The cell parameters were calculated in the previous problem and will not be repeated here. Detailed output is desired.

The input data form, data deck listing, and computer output are shown in figures 8, 9, and 10.

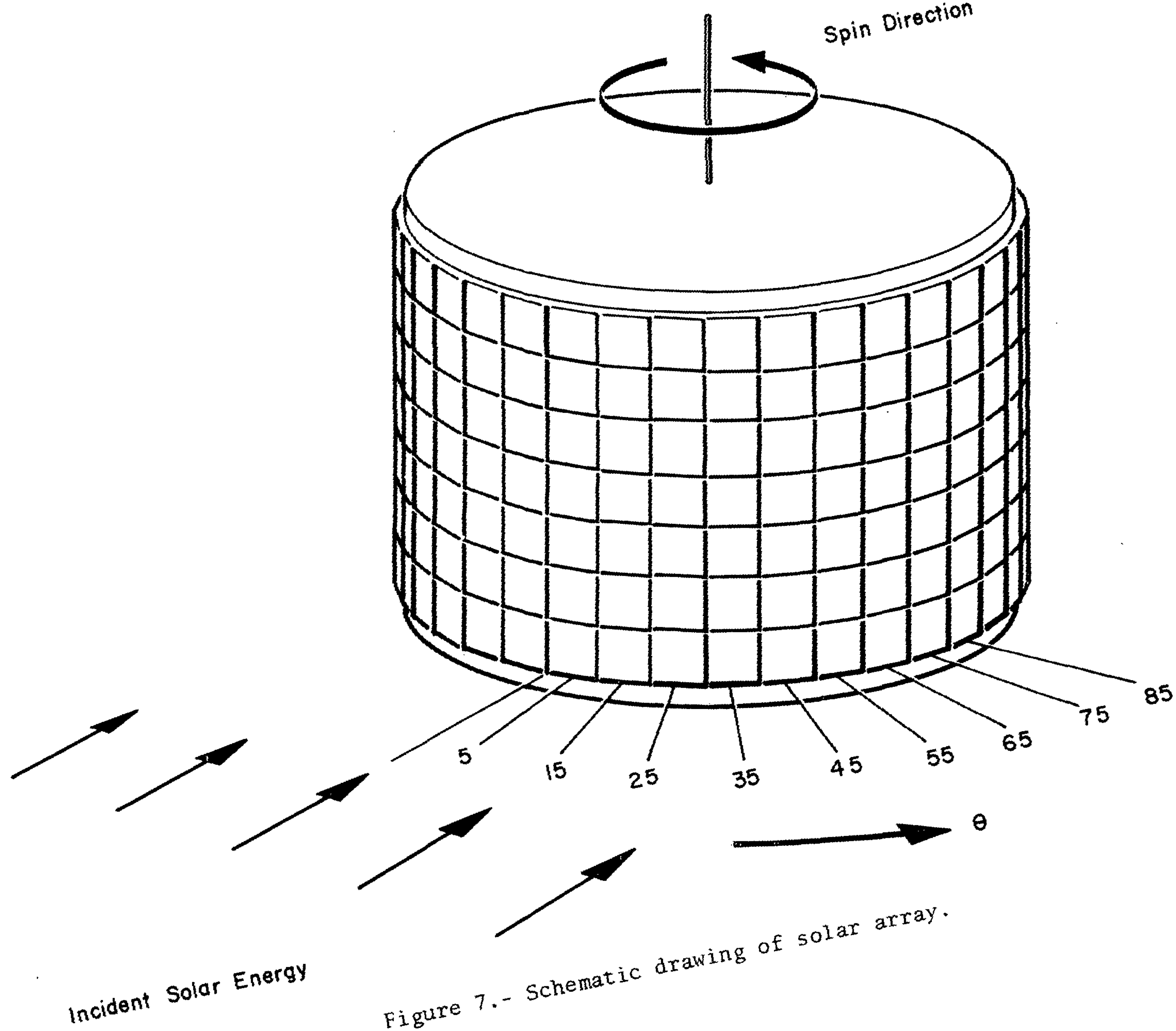


Figure 7.- Schematic drawing of solar array.

INPUT DATA - SOLAR CELL PERFORMANCE PROGRAM

FORMAT INPUT DATA

A6 RUN 2

12A6 TITLE CARD Sample Problem 2 - Array Calculation

6I10 NAU 1 NTHETA 9 KPLOT 0 KOUT 1 INT 0 INR 0 INTD 0 INRD 0

8F10.4	AU	0.50							
	TEMP	360.							
	A	1.43							
	VCL	0.21							

AREA 2.0 TREF 303. VREF 594. IREF 60.0 XJLTR 0. ATX .00035

BRS 2.0 RS 0.11

THETA	5.	15.	25.	35.	45.	55.	65.	75.
	85.							
FTHETA	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667
	2.667							

NIS 4. VIS 54. SCL 0.5

PLOT CARD Not used - delete

TABLES

TRANSMISSION (TRANS) Not used - delete

RESPONSE (RESP) Not used - delete

TRANSMISSION DAMAGE (DTRANS) Not used - delete

RESPONSE DAMAGE (DRESP) Not used - delete

COMMENTS Array calculation with a minimum of required input information

Figure 8.- Input data form - Sample Problem 2

```
RUN 2
                SAMPLE PROBLEM 2 - ARRAY CALCULATION
     1           9          0          1          0          0          0          0
  0.50
  360.
  1.43
  0.21
   2.0        303.       594.       60.0        0.     .00035        2.        .11
    5.         15.        25.        35.        45.        55.        65.        75.
   85.
 2.667       2.667      2.667      2.667      2.667      2.667      2.667      2.667
 2.667
    4.         54.        0.5
```

Figure 9.- Data deck - Sample Problem 2.

```
INPUT DATA      RUN 2                      SAMPLE PROBLEM 2 - ARRAY CALCULATION


            NAU=  1
         NTHETA=  9
          KPLOT=  0
           KOUT=  1
           AREA= 0.20000000E 01
           TREF= 0.30300000E 03
           VREF= 0.59400000E 03
           IREF= 0.60000000E 02
          XJLTR= 0.0
            ATX= 0.34999987E-03
            BRS= 0.20000000E 01
             RS= 0.10999995E 00
```

Figure 10.- Output - Sample Problem 2.

12/01/69

SOLAR CELL PERFORMANCE
RUN 2

SAMPLE PROBLEM 2 - ARRAY CALCULATION

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=60.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (SINGLE CELL)

AU= 0.50 THETA = 5.00 TC =360.0 JLTR = 0.21428567E 00 VCL =0.21
IL = 0.24385635E 03 IO = 0.20633431E-02 VOC = 0.51860962E 03 A = 1.43

I	CURRENT(MA)	VOLTAGE(MV)
1	0.24385635E 03	0.0
2	0.24385635E 03	0.10000000E 02
3	0.24385635E 03	0.20000000E 02
4	0.24385635E 03	0.30000000E 02
5	0.24385635E 03	0.40000000E 02
6	0.24385635E 03	0.50000000E 02
7	0.24384383E 03	0.60000000E 02
8	0.24384383E 03	0.70000000E 02
9	0.24384383E 03	0.80000000E 02
10	0.24382976E 03	0.90000000E 02
11	0.24382253E 03	0.10000000E 03
12	0.24382150E 03	0.11000000E 03
13	0.24380209E 03	0.12000000E 03
14	0.24378787E 03	0.13000000E 03
15	0.24377814E 03	0.14000000E 03
16	0.24374774E 03	0.15000000E 03
17	0.24371982E 03	0.16000000E 03
18	0.24369415E 03	0.17000000E 03
19	0.24364099E 03	0.18000000E 03
20	0.24358611E 03	0.19000000E 03
21	0.24351736E 03	0.20000000E 03
22	0.24343398E 03	0.21000000E 03
23	0.24332359E 03	0.22000000E 03
24	0.24318596E 03	0.23000000E 03
25	0.24302032E 03	0.24000000E 03
26	0.24280867E 03	0.25000000E 03
27	0.24255042E 03	0.26000000E 03
28	0.24221378E 03	0.27000000E 03
29	0.24179807E 03	0.28000000E 03
30	0.24128394E 03	0.29000000E 03
31	0.24063879E 03	0.30000000E 03
32	0.23983357E 03	0.31000000E 03
33	0.23882944E 03	0.32000000E 03
34	0.23757864E 03	0.33000000E 03
35	0.23602267E 03	0.34000000E 03
36	0.23409032E 03	0.35000000E 03
37	0.23169537E 03	0.36000000E 03
38	0.22873441E 03	0.37000000E 03
39	0.22508467E 03	0.38000000E 03
40	0.22060242E 03	0.39000000E 03
41	0.21512106E 03	0.40000000E 03
42	0.20845224E 03	0.41000000E 03
43	0.20038654E 03	0.42000000E 03
44	0.19069771E 03	0.43000000E 03
45	0.17914865E 03	0.44000000E 03
46	0.16549896E 03	0.45000000E 03
47	0.14951714E 03	0.46000000E 03
48	0.13098114E 03	0.47000000E 03
49	0.10972241E 03	0.48000000E 03
50	0.85590958E 02	0.49000000E 03
51	0.58487442E 02	0.50000000E 03
52	0.28366730E 02	0.51000000E 03
53	0.0	0.51860962E 03

NOTE: Similar data are printed for each angle but have been omitted in this figure.

Figure 10.- Continued.

SOLAR CELL PERFORMANCE
RUN 2

SAMPLE PROBLEM 2 - ARRAY CALCULATION

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=60.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (COMPLETE ARRAY)

AU = 0.5000 TC = 360.0000

NIS = 4.00 VIS = 54.00 SCL = 0.50000000E 00

THETAS =	5.00	15.00	25.00	35.00	45.00
THETAS =	55.00	65.00	75.00	85.00	
FTHETAS =	2.67	2.67	2.67	2.67	2.67
FTHETAS =	2.67	2.67	2.67	2.67	

I	CURRENT(AMPS)	VOLTAGE(VOLTS)
1	0.14981200E 02	0.0
2	0.14981203E 02	0.10000000E 01
3	0.14981274E 02	0.20000000E 01
4	0.14980529E 02	0.30000000E 01
5	0.14980104E 02	0.40000000E 01
6	0.14978915E 02	0.50000000E 01
7	0.14977575E 02	0.60000000E 01
8	0.14975716E 02	0.70000000E 01
9	0.14972413E 02	0.80000000E 01
10	0.14967646E 02	0.90000000E 01
11	0.14960480E 02	0.10000000E 02
12	0.14949732E 02	0.11000000E 02
13	0.14933014E 02	0.12000000E 02
14	0.14908407E 02	0.13000000E 02
15	0.14870512E 02	0.14000000E 02
16	0.14813605E 02	0.15000000E 02
17	0.14727546E 02	0.16000000E 02
18	0.14597622E 02	0.17000000E 02
19	0.14402163E 02	0.18000000E 02
20	0.14109879E 02	0.19000000E 02
21	0.13675360E 02	0.20000000E 02
22	0.13036803E 02	0.21000000E 02
23	0.12109967E 02	0.22000000E 02
24	0.10788912E 02	0.23000000E 02
25	0.89494381E 01	0.24000000E 02
26	0.64611082E 01	0.25000000E 02
27	0.34832869E 01	0.26000000E 02
28	0.76419097E 00	0.27000000E 02

I(PMAX) = 0.13369101E 02 V(PMAX) = 0.20535751E 02 P(MAX) = 0.27459644E 03

Figure 10.- Concluded.

SAMPLE PROBLEM 3 – FILTERED SOLAR CELL

The reduction in electrical output created by a blue-red filter is sought for the cell of Sample Problem 1. Table 1 lists the relative spectral response of the cell as well as the transmission of the coverglass filter. To illustrate the input procedure for response and transmission values that are a function of wavelength only, the temperature and angular effects have been neglected.

When a value for IREF and a value of -1 for XJLTR are entered, the computer will calculate a value for CONST and then integrate the product of spectral response, transmission, and solar spectrum to obtain a true value of XJLTR for use in determining the light-generated current. To enable a comparison to be made with Sample Problem 1, AU = 0.50 and T = 360° K.

The input data form, data deck listing, and computer output are shown in figures 11, 12, and 13.

TABLE 1.- TRANSMISSION AND RELATIVE RESPONSE VERSUS WAVELENGTH

WAVE, μ	RESP	TRANS	WAVE, μ	RESP	TRANS
0.30	0.00	0.00	0.85	0.98	0.95
.35	.05	.01	.90	.88	.94
.40	.10	.82	.95	.63	.93
.45	.23	.88	1.00	.37	.89
.55	.52	.90	1.05	.14	.90
.65	.80	.87	1.10	.05	.55
.75	.94	.95	1.15	.00	.10
.80	.99	.95	1.30	.00	.02

INPUT DATA - SOLAR CELL PERFORMANCE PROGRAM

FORMAT INPUT DATA

A6 RUN 3

12A6 TITLE CARD Sample Problem 3 - Filtered Solar Cell

6I10 NAU 1 NTHETA 1 KPLOT 0 KOUT 1 INT 1 INR 1 INTD 0 INRD 0

8F10.4 AU 0.50

TEMP 360.

A 1.43

VCL 0.21

AREA 2.0 TREF 303. VREF 594. IREF 60.0 XJLTR -1. ATX .00035

BRS 2.0 RS 0.11

THETA 0.

FTHETA 1.

NIS 0. VIS SCL

PLOT CARD Not used - delete

TABLES

TRANSMISSION (TRANS) Table 1

RESPONSE (RESP) Table 1

TRANSMISSION DAMAGE (DTRANS) Not used - delete

RESPONSE DAMAGE (DRESP) Not used - delete

COMMENTS Filtered cell calculations illustrating single variable tables

Figure 11.- Input data form - Sample Problem 3.

```
RUN 3
                SAMPLE PROBLEM 3 - FILTERED SOLAR CELL
   1        1        0        1        1        1        0        0
 0.5
360.
1.43
0.21
 2.0     303.     594.     60.0      -1.   .00035       2.      .11
  0.
  1.
  0.
  16
 .30      .35      .40      .45      .55      .65      .75      .80
 .85      .90      .95     1.00     1.05     1.10     1.15     1.30
 .00      .01      .82      .88      .90      .87      .95      .95
 .95      .94      .93      .89      .90      .55      .10      .02
  16
 .30      .35      .40      .45      .55      .65      .75      .80
 .85      .90      .95     1.00     1.05     1.10     1.15     1.30
 .00      .05      .10      .23      .52      .80      .94      .99
 .98      .88      .63      .37      .14      .05      .00      .00
```

Figure 12.- Data deck - Sample Problem 3.

```
INPUT DATA     RUN 3                  SAMPLE PROBLEM 3 - FILTERED SOLAR CELL


          NAU=  1
       NTHETA=  1
        KPLOT=  0
         KOUT=  1
         AREA= 0.20000000E 01
         TREF= 0.30300000E 03
         VREF= 0.59400000E 03
         IREF= 0.60000000E 02
        XJLTR=-0.10000000E 01
          ATX= 0.34999987E-03
          BRS= 0.20000000E 01
           RS= 0.10999995E 00


ABSOLUTE RESPONSE/RELATIVE RESPONSE =    0.53334
```

Figure 13.- Output - Sample Problem 3.

SOLAR CELL PERFORMANCE
RUN 3

SAMPLE PROBLEM 3 - FILTERED SOLAR CELL

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=60.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (SINGLE CELL)

AU= 0.50 THETA = 0.0 TC =360.0 JLTR = 0.19393480E 00 VCL =0.21
IL = 0.22154022E 03 IO = 0.20831837E-02 VOC = 0.51392334E 03 A = 1.43

I	CURRENT(MA)	VOLTAGE(MV)
1	0.22154022E 03	0.0
2	0.22154022E 03	0.10000000E 02
3	0.22154022E 03	0.20000000E 02
4	0.22154022E 03	0.30000000E 02
5	0.22154022E 03	0.40000000E 02
6	0.22154022E 03	0.50000000E 02
7	0.22152837E 03	0.60000000E 02
8	0.22152837E 03	0.70000000E 02
9	0.22152837E 03	0.80000000E 02
10	0.22151492E 03	0.90000000E 02
11	0.22150801E 03	0.10000000E 03
12	0.22150705E 03	0.11000000E 03
13	0.22148849E 03	0.12000000E 03
14	0.22147491E 03	0.13000000E 03
15	0.22146600E 03	0.14000000E 03
16	0.22143657E 03	0.15000000E 03
17	0.22140990E 03	0.16000000E 03
18	0.22138596E 03	0.17000000E 03
19	0.22133458E 03	0.18000000E 03
20	0.22128215E 03	0.19000000E 03
21	0.22121649E 03	0.20000000E 03
22	0.22113751E 03	0.21000000E 03
23	0.22103134E 03	0.22000000E 03
24	0.22089728E 03	0.23000000E 03
25	0.22073517E 03	0.24000000E 03
26	0.22054456E 03	0.25000000E 03
27	0.22028679E 03	0.26000000E 03
28	0.21996173E 03	0.27000000E 03
29	0.21956877E 03	0.28000000E 03
30	0.21908218E 03	0.29000000E 03
31	0.21846545E 03	0.30000000E 03
32	0.21769563E 03	0.31000000E 03
33	0.21673543E 03	0.32000000E 03
34	0.21553905E 03	0.33000000E 03
35	0.21405034E 03	0.34000000E 03
36	0.21220084E 03	0.35000000E 03
37	0.20990753E 03	0.36000000E 03
38	0.20707069E 03	0.37000000E 03
39	0.20357182E 03	0.38000000E 03
40	0.19927115E 03	0.39000000E 03
41	0.19400714E 03	0.40000000E 03
42	0.18759572E 03	0.41000000E 03
43	0.17983128E 03	0.42000000E 03
44	0.17049097E 03	0.43000000E 03
45	0.15933893E 03	0.44000000E 03
46	0.14613478E 03	0.45000000E 03
47	0.13064433E 03	0.46000000E 03
48	0.11264912E 03	0.47000000E 03
49	0.91950241E 02	0.48000000E 03
50	0.68411240E 02	0.49000000E 03
51	0.41916611E 02	0.50000000E 03
52	0.12412240E 02	0.51000000E 03
53	0.0	0.51392334E 03

I(PMAX) = 0.19800998E 03 V(PMAX) = 0.39260571E 03 P(MAX) = 0.77741623E 02

Figure 13.- Concluded.

SAMPLE PROBLEM 4 – SIMULATED SOLAR ENERGY

Laboratory tests are scheduled for the cell described in Sample Problem 3. The spectral energy output of the solar simulator is tabulated in table 2. What differences in cell performance can be expected under simulated conditions for 0.50 AU?

Information on the spectral energy distribution of the source is placed in the first three data statements of subroutine RESPE. These contain a list of wavelengths, the ratios of energy in the bandwidths centered at these wavelengths to the total energy output, and the total number of wavelengths listed. Figure 14 illustrates the placement of the statements.

The input data form, data deck listing, and computer output are shown in figures 15, 16, and 17.

TABLE 2.- SOLAR SIMULATOR SPECTRUM

WAVE[a]	LSOLAR[b]	WAVE[a]	LSOLAR[b]
0.31	0.0174	0.83	0.0181
.33	.0056	.85	.0283
.35	.0072	.87	.0066
.37	.0183	.89	.0084
.39	.0243	.91	.0139
.41	.0286	.93	.0113
.43	.0298	.95	.0080
.45	.0320	.97	.0090
.47	.0339	.99	.0086
.49	.0358	1.01	.0093
.51	.0342	1.03	.0071
.53	.0311	1.05	.0044
.55	.0306	1.07	.0061
.57	.0312	1.09	.0061
.59	.0296	1.11	.0089
.61	.0284	1.13	.0121
.63	.0278	1.15	.0068
.65	.0264	1.17	.0065
.67	.0251	1.19	.0139
.69	.0249	1.21	.0091
.71	.0252	1.23	.0052
.73	.0218	1.25	.0046
.75	.0213	1.27	.0046
.77	.0213	1.29	.0075
.79	.0218	1.31	.0039
.81	.0177		

[a]Center wavelength of 0.02 μ band.

[b]Energy in 0.02 μ band/total energy output.

```
C SUBROUTINE RESPE  - INTERPOLATION
      SUBROUTINE RESPE(THET,TC,AUC,FJLTR,KT)
      REAL IREF,LSOLAR,LREF
      DIMENSION         XYZ(3),XYZ1(3),XYZ2(3),XYZ3(3),NXYZ(3),NXYZ1(3),
     1          NXYZ2(3),NXYZ3(3),TINV(150),TDINV(150),RINV(150),
     2          RDINV(150),TARG(1260),TDARG(1260),RARG(1260),RDARG(1260),
     3          PARDER(3),WAVE(90),LSOLAR(90),RWAVE(90),LREF(90),
     4          TRANS(90),DTRANS(90),RESP(90),DRESP(90),FACTOR(90)
      COMMON /COM1/AREA,IREF,TREF,INT,INR,INTD,INRD
C SUBSTITUTION OF XENON - KRYPTON SPECTRUM FOR SULAR SPECTRUM
C    CENTER WAVELENGTH OF 0.02 MICRON BANDWIDTH UF ENERGY SOURCE
      DATA WAVE/0.31,0.33,0.35,0.37,0.39,0.41,0.43,0.45,0.47,0.49,0.51,
     1           0.53,0.55,0.57,0.59,0.61,0.63,0.65,0.67,0.69,0.71,0.73,
     2           0.75,0.77,0.79,0.81,0.83,0.85,0.87,0.89,0.91,0.93,0.95,
     3           0.97,0.99,1.01,1.03,1.05,1.07,1.09,1.11,1.13,1.15,1.17,
     4           1.19,1.21,1.23,1.25,1.27,1.29,1.30/
C    FRACTION OF TOTAL ENERGY IN BANDWIDTH  OF ENERGY SOURCE
C                       (RELATIVE DISTRIBUTION)
      DATA LSOLAR/.0174,.0056,.0072,.0183,.0243,.0286,.0298,.0320,.0339,
     1           .0350,. 0342,.0311,.0306,.0312,.0296,.0284,.0278,.0264,
     2           .0251,.0249,.0252,.0218,.0213,.0213,.0218,.0177,.0181,
     3           .0283,.0066,.0084,.0139,.0113,.0080,.0090,.0086,.0093,
     4           .0071,.0044,.0061,.0061,.0089,.0121,.0068,.0065,.0139,
     5           .0091,.0052,.0046,.0046,.0075,.0039/
C    NW IS THE NUMBER OF VOLUES IN THE WAVE AND LSOLAR ARRAYS AND MUST
C                  BE REDEFINED IF THE ARRAY SIZE IS CHANGED
      DATA NW/51/
C    CENTER WAVELENGTH OF 0.02 MICRON BANDWIDTH UF ENERGY SUURCE USED TO
C                  OBTAIN IREF
      DATA RWAVE/0.31,0.33,0.35,0.37,0.39,0.41,0.43,0.45,0.47,0.49,0.51,
     1           0.53,0.55,0.57,0.59,0.61,0.63,0.65,0.67,0.69,0.71,0.73,
     2           0.75,0.77,0.79,0.81,0.83,0.85,0.87,0.89,0.91,0.93,0.95,
     3           0.97,0.99,1.02,1.06,1.10,1.14,1.18,1.22,1.26,1.30/
C    FRACTION OF TOTAL ENERGY IN BANDWIDTH  OF ENERGY SOURCE
C                       (RELATIVE DISTRIBUTION)
      DATA  LREF /.0103,.0154,.0167,.0182,.0174,.0267,.0270,.0310,.0310,
     1           .0290,.0280,.0270,.0280,.0270,.0270,.0250,.0240,.0240,
     2           .0220,.0210,.0200,.0190,.0180,.0180,.0160,.0160,.0160,
     3           .0140,.0140,.0140,.0130,.0120,.0110,.0110,.0110,.0210,
     4           .0180,.0170,.0160,.0150,.0140,.0130,.0120/
C    NP IS THE NUMBER OF VALUES IN THE RWAVE AND LREF ARRAYS AND MUST
C                  BE REDEFINED IF THE ARRAY SIZE IS CHANGED
      DATA  NP/43/
C        TIRR IS TOTAL IRRADIANCE IN MV/SQ.CM. OF SOURCE,LREF, USED TO
C                  OBTAIN IREF
```

Figure 14.- Energy spectrum substitution in subroutine RESPE.

INPUT DATA - SOLAR CELL PERFORMANCE PROGRAM

FORMAT INPUT DATA

A6 RUN 4

12A6 TITLE CARD Sample Problem 4 - Simulated Solar Energy

6I10 NAU 1 NTHETA 1 KPLOT 0 KOUT 1 INT 1 INR 1 INTD 0 INRD 0

8F10.4 AU 0.50

TEMP 360.

A 1.43

VCL 0.21

AREA 2.0 TREF 303. VREF 594. IREF 60.0 XJLTR -1. ATX .00035

BRS 2.0 RS 0.11

THETA 0.0

FTHETA 1.0

NIS 0. VIS ______ SCL ______

PLOT CARD Not used - delete

TABLES

TRANSMISSION (TRANS) Table 1

RESPONSE (RESP) Table 1

TRANSMISSION DAMAGE (DTRANS) Not used - delete

RESPONSE DAMAGE (DRESP) Not used - delete

COMMENTS Illustrates input procedure for energy sources other than the sun

Figure 15.- Input data form - Sample Problem 4.

```
RUN 4
                  SAMPLE PROBLEM 4 - SIMULATED SOLAR ENERGY
          1         1          0          1          1          1
        0.5
       360.
       1.43
       0.21
        2.0       303.       594.       60.0        -1.     .00035         2.        .11
         0.
         1.
         0.
         16
        .30        .35        .40        .45        .55        .65        .75        .80
        .85        .90        .95       1.00       1.05       1.10       1.15       1.30
        .00        .01        .82        .88        .90        .87        .95        .95
        .95        .94        .93        .89        .90        .55        .10        .02
         16
        .30        .35        .40        .45        .55        .65        .75        .80
        .85        .90        .95       1.00       1.05       1.10       1.15       1.30
        .00        .05        .10        .23        .52        .80        .94        .99
        .98        .88        .63        .37        .14        .05        .00        .00
```

Figure 16.- Data deck - Sample Problem 4.

```
INPUT DATA      RUN 4                    SAMPLE PROBLEM 4 - SIMULATED SOLAR ENERGY

           NAU=  1
        NTHETA=  1
         KPLOT=  0
          KOUT=  1
          AREA= 0.20000000E 01
          TREF= 0.30300000E 03
          VREF= 0.59400000E 03
          IREF= 0.60000000E 02
        XJLTR=-0.10000000E 01
           ATX= 0.34999987E-03
           BRS= 0.20000000E 01
            RS= 0.10999995E 00


ABSOLUTE RESPONSE/RELATIVE RESPONSE =    0.53334
```

Figure 17.- Sample Problem 4.

12/03/69

SOLAR CELL PERFORMANCE
RUN 4

SAMPLE PROBLEM 4 - SIMULATED SOLAR ENERGY

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=60.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (SINGLE CELL)

AU= 0.50 THETA = 0.0 TC =360.0 JLTR = 0.21651047E 00 VCL =0.21
IL = 0.24732941E 03 IO = 0.20586273E-02 VOC = 0.51933911E 03 A = 1.43

I	CURRENT (MA)	VOLTAGE(MV)
1	0.24732941E 03	0.0
2	0.24732941E 03	0.10000000E 02
3	0.24732941E 03	0.20000000E 02
4	0.24732941E 03	0.30000000E 02
5	0.24732941E 03	0.40000000E 02
6	0.24732941E 03	0.50000000E 02
7	0.24731679E 03	0.60000000E 02
8	0.24731679E 03	0.70000000E 02
9	0.24731679E 03	0.80000000E 02
10	0.24730263E 03	0.90000000E 02
11	0.24729533E 03	0.10000000E 03
12	0.24729416E 03	0.11000000E 03
13	0.24727478E 03	0.12000000E 03
14	0.24726048E 03	0.13000000E 03
15	0.24725079E 03	0.14000000E 03
16	0.24722009E 03	0.15000000E 03
17	0.24719199E 03	0.16000000E 03
18	0.24716603E 03	0.17000000E 03
19	0.24711266E 03	0.18000000E 03
20	0.24705743E 03	0.19000000E 03
21	0.24698827E 03	0.20000000E 03
22	0.24690430E 03	0.21000000E 03
23	0.24679326E 03	0.22000000E 03
24	0.24665431E 03	0.23000000E 03
25	0.24648752E 03	0.24000000E 03
26	0.24627507E 03	0.25000000E 03
27	0.24601642E 03	0.26000000E 03
28	0.24567645E 03	0.27000000E 03
29	0.24525470E 03	0.28000000E 03
30	0.24474078E 03	0.29000000E 03
31	0.24409163E 03	0.30000000E 03
32	0.24328137E 03	0.31000000E 03
33	0.24227103E 03	0.32000000E 03
34	0.24101250E 03	0.33000000E 03
35	0.23944702E 03	0.34000000E 03
36	0.23750293E 03	0.35000000E 03
37	0.23509358E 03	0.36000000E 03
38	0.23211507E 03	0.37000000E 03
39	0.22844409E 03	0.38000000E 03
40	0.22393616E 03	0.39000000E 03
41	0.21842412E 03	0.40000000E 03
42	0.21171901E 03	0.41000000E 03
43	0.20361093E 03	0.42000000E 03
44	0.19387337E 03	0.43000000E 03
45	0.18226833E 03	0.44000000E 03
46	0.16855675E 03	0.45000000E 03
47	0.15250624E 03	0.46000000E 03
48	0.13390392E 03	0.47000000E 03
49	0.11255859E 03	0.48000000E 03
50	0.88345016E 02	0.49000000E 03
51	0.61157120E 02	0.50000000E 03
52	0.30951050E 02	0.51000000E 03
53	0.0	0.51933911E 03

I(PMAX) = 0.22099785E 03 V(PMAX) = 0.39559741E 03 P(MAX) = 0.87428238E 02

Figure 17.- Concluded.

SAMPLE PROBLEM 5 – COMPLETE MISSION ANALYSIS

The output characteristics of the solar array described in Sample Problem 2 are to be determined for a typical heliocentric orbit with perihelion at 0.4 AU. The cells are similar to those of Sample Problem 3 and have transmission and response values as shown in tables 3 and 4. To illustrate the bivariant use of the tables, the relative response is shown to be a variable of wavelength and incident angle. Transmission is a function of wavelength, incidence angle, and temperature to demonstrate the trivariant capability of the program.

The reduced response of the cells at high angles of incidence is due to an experimentally determined decrease in output due to factors other than the cosine reduction in incident energy and the spectral transmission shift of the filters.

Data on transmission damage to coverglasses and response damage to the solar cells have been compiled into tables 5 and 6 for a typical heliocentric orbit. Note that it is the difference between the degraded and undegraded values that is used in the tables.

The value of CONST has previously been determined to be 0.533 and may be entered directly by setting IREF equal to -1 and entering 0.533 for XJLTR.

Calculations will be made at 1.0, 0.8, 0.6, and 0.4 AU. The corresponding panel temperatures are expected to be 285°, 320°, 367°, and 450° K, respectively. Values for A and VCL are obtained from figures 1 and 18, respectively. Neither plotting nor detailed output is desired.

The input data form, data deck listing, and computer output are shown in figures 19, 20, and 21.

TABLE 3.- FILTER TRANSMISSION (TRANS) VERSUS WAVELENGTH (KWAVE), INCIDENCE ANGLE (KTHET), AND TEMPERATURE (KTEMP)

	200°–340° K						500° K					
λ, μ	0°	15°	30°	45°	60°	90°	0°	15°	30°	45°	60°	90°
300	0	0	0	0	0	0	0	0	0	0	0	0
350	.01	.01	.01	.01	.01	.10	.01	.01	.01	.10	.01	.15
370	.02	.02	.02	.09	.20	.40	.05	.06	.12	.40	.60	.80
380	.06	.06	.12	.40	.60	.85	.40	.42	.57	.75	.80	.85
390	.42	.42	.57	.75	.85	.80	.83	.80	.82	.84	.88	.90
400	.82	.80	.82	.84	.82	.75	.82	.80	.82	.84	.82	.75
410	.85	.85	.85	.84	.80	.73	.83	.83	.83	.81	.78	.71
460	.88	.87	.86	.84	.80	.75	.86	.85	.84	.82	.78	.73
550	.90	.89	.88	.86	.82	.77	.88	.87	.86	.84	.80	.75
620	.91	.90	.88	.80	.76	.70	.89	.88	.85	.78	.74	.68
640	.90	.89	.83	.86	.80	.76	.88	.87	.81	.84	.78	.74
650	.87	.86	.84	.87	.82	.78	.85	.84	.82	.85	.80	.76
670	.92	.91	.91	.90	.85	.80	.89	.87	.87	.86	.82	.78
700	.92	.91	.93	.92	.87	.85	.90	.89	.91	.90	.85	.83
750	.95	.94	.92	.92	.90	.87	.92	.91	.89	.89	.87	.84
850	.95	.94	.95	.90	.85	.77	.92	.91	.92	.87	.82	.74
950	.93	.93	.88	.85	.70	.50	.90	.90	.85	.82	.67	.48
1000	.89	.88	.90	.56	.25	.05	.86	.85	.77	.53	.10	.02
1050	.90	.91	.60	.15	.02	.02	.40	.39	.37	.23	.02	.02
1100	.55	.10	.10	.04	.03	.04	.02	.02	.02	.02	.02	.02
1150	.10	.04	.03	.04	.08	.10	.02	.04	.06	.08	.10	.12
1200	.02	.02	.02	.05	.10	.20	.02	.05	.10	.15	.25	.30
1250	.02	.02	.03	.10	.30	.50	.02	.10	.20	.40	.65	.70
1300	.02	.03	.05	.25	.65	.70	.05	.30	.40	.65	.70	.75

TABLE 4.- RELATIVE SPECTRAL RESPONSE (RESP) VERSUS WAVELENGTH (MWAVE) AND INCIDENCE ANGLE (MTHETA)

λ, μ	0°	45°	60°	75°	85°	90°
0.30	0	0	0	0	0	0
.35	.05	.049	.048	.044	.038	.033
.40	.100	.099	.096	.088	.075	.065
.45	.230	.228	.221	.202	.173	.150
.55	.520	.514	.499	.458	.390	.338
.65	.80	.792	.768	.704	.600	.520
.75	.940	.931	.902	.827	.705	.611
.80	.990	.980	.950	.871	.743	.644
.85	.980	.970	.941	.862	.735	.637
.90	.880	.871	.845	.774	.660	.572
.95	.630	.624	.605	.554	.473	.410
1.00	.370	.366	.355	.326	.278	.241
1.05	.140	.139	.134	.123	.105	.091
1.10	.050	.049	.048	.044	.038	.033
1.15	.000	.000	.000	.000	.000	.000
1.30	.000	.000	.000	.000	.000	.000

TABLE 5.- TRANSMISSION DAMAGE (DTRANS) VERSUS WAVELENGTH (LWAVE) AND AU (LAU)

[$\theta = 0°$ to $90°$]

AU	λ, μ	UV	Proton	Total damage
1.0	0.30	0.000	0.000	0.000
	.35			
	.38			
	.40			
	.50			
	.60			
	1.0			
	1.3			
0.8	.30	.00	.005	.005
	.35	.00	.005	.005
	.38	.012	.004	.016
	.40	.006	.003	.009
	.50	.012	.002	.014
	.60	.002	.002	.004
	1.00	.00	.000	
	1.30	.00	.000	
0.6	.30	.00	.008	.008
	.35	.00	.008	.008
	.38	.018	.006	.024
	.40	.009	.006	.015
	.50	.018	.003	.021
	.60	.003	.002	.005
	1.00	.00	.000	
	1.30	.00	.000	
0.4	.30	.00	.02	.02
	.35	.00	.018	.018
	.38	.033	.015	.048
	.40	.016	.013	.029
	.50	.033	.007	.040
	.60	.006	.006	.012
	1.00	.00	.001	.001
	1.30	.00	.001	.001
0.2	.30	.00	.12	.12
	.35	.00	.11	.11
	.38	.30	.09	.39
	.40	.15	.08	.23
	.50	.30	.045	.345
	.60	.05	.035	.085
	1.00	.00	.015	.015
	1.30	.00	.010	.01

TABLE 6.- RESPONSE DAMAGE VERSUS WAVELENGTH (JWAVE) AND AU (JAU)

[$\theta = 0°$ to $90°$]

AU	λ, μ	Damage
1.0	0.3	0.000
	.8	.000
	1.1	.000
	1.3	.000
0.6	.3	.002
	.8	.01
	1.1	.002
	1.3	.002
0.4	.3	.002
	.8	.020
	1.1	.006
	1.3	.004
0.2	.3	.006
	.8	.030
	1.1	.010
	1.3	.007

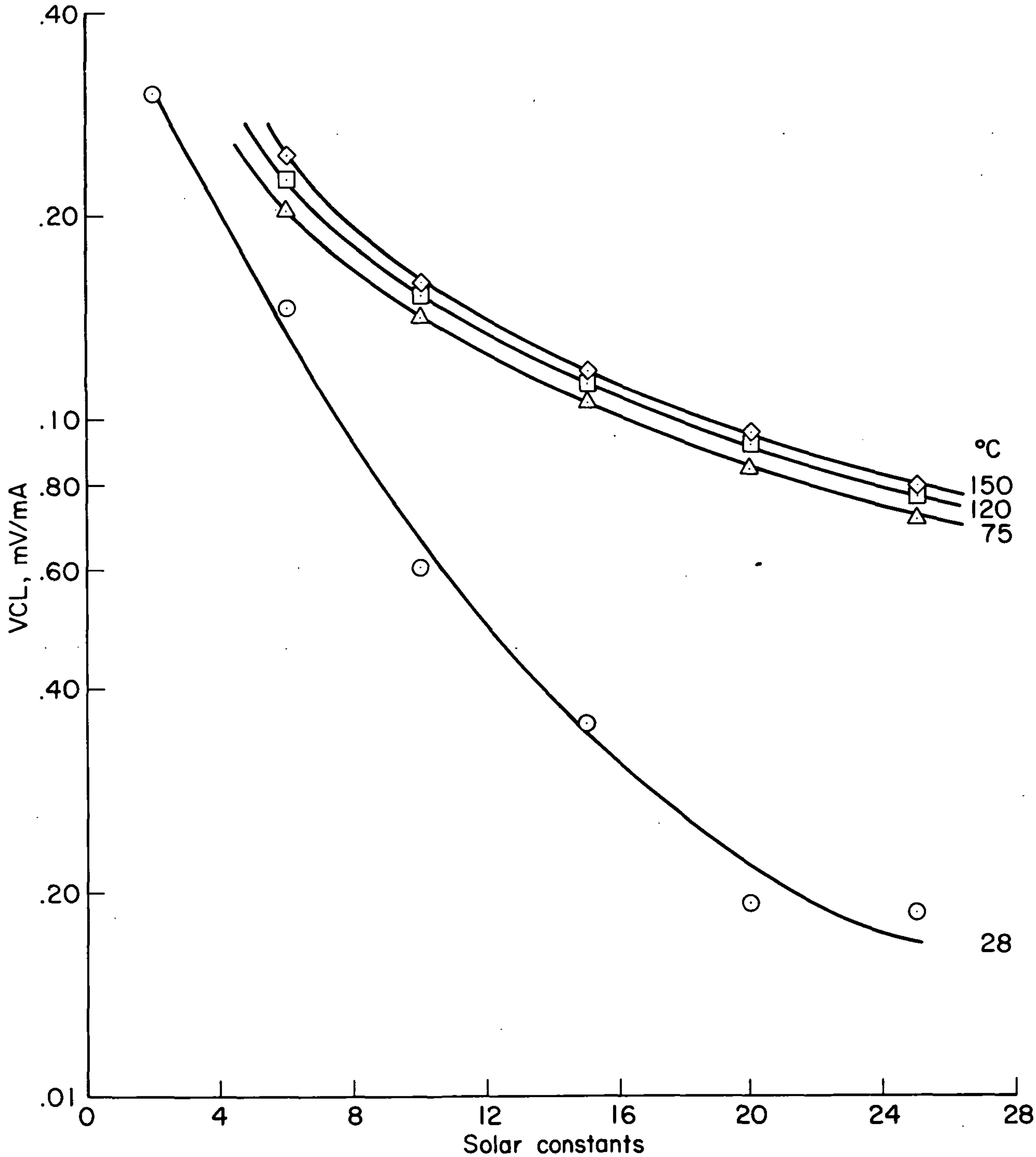


Figure 18.- Solar constants.

INPUT DATA - SOLAR CELL PERFORMANCE PROGRAM

FORMAT INPUT DATA

A6 RUN 5

12A6 TITLE CARD Sample Problem 5 - Complete Mission Analysis

6I10 NAU 4 NTHETA 9 KPLOT 0 KOUT 0 INT 3 INR 2 INTD 2 INRD 2

8F10.4	AU	1.0	0.8	0.6	0.4				
	TEMP	285.	320.	367.	450.				
	A	2.0	1.90	1.62	1.22				
	VCL	0.30	0.28	0.26	0.24				

AREA 2.0 TREF 303. VREF 594. IREF -1. XJLTR 0.533 ATX .00035

BRS 2.0 RS 0.11

THETA	5.	15.	25.	35.	45.	55.	65.	75.
	85.							
FTHETA	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667
	2.667							

NIS 4. VIS 54. SCL 0.5

PLOT CARD Not used - delete

TABLES

TRANSMISSION (TRANS) Table 3

RESPONSE (RESP) Table 4

TRANSMISSION DAMAGE (DTRANS) Table 5

RESPONSE DAMAGE (DRESP) Table 6

COMMENTS Array calculation including radiation damage and direct input of CONST

Figure 19.- Input Data Form - Sample Problem 5.

```
RUN 5
          SAMPLE PROBLEM 5 - COMPLETE MISSION ANALYSIS
         4         9         0         0         3         2         2         2
       1.0       0.8       0.6       0.4
      285.      320.      367.      450.
       2.0       1.9      1.62      1.22
      0.30      0.28      0.26      0.24
       2.0      303.      594.       -1.     0.533   0.00035       2.0      0.11
        5.       15.       25.       35.       45.       55.       65.       75.
       85.
     2.667     2.667     2.667     2.667     2.667     2.667     2.667     2.667
     2.667
        4.       54.       0.5
        24         6         3
      .300      .350      .370      .380      .390      .400      .410      .460
      .550      .620      .640      .650      .670      .700      .750      .850
      .950     1.000     1.050     1.100     1.150     1.200     1.250     1.300
        0.       15.       30.       45.       60.       90.      200.      340.
      500.
        .0       .01       .02       .06       .42       .82       .85       .88
       .90       .91       .90       .87       .92       .92       .95       .95
       .93       .89       .90       .55       .10       .02       .02       .02
        .0       .01       .02       .06       .42       .80       .85       .87
       .89       .90       .89       .86       .91       .91       .94       .94
       .93       .88       .91       .10       .04       .02       .02       .03
        .0       .01       .02       .12       .57       .82       .85       .86
       .88       .88       .83       .84       .91       .93       .92       .95
       .88       .90       .60       .10       .03       .02       .03       .05
        .0       .01       .09       .40       .75       .84       .84       .84
       .86       .80       .86       .87       .90       .92       .92       .90
       .85       .56       .15       .04       .04       .05       .10       .25
        .0       .01       .20       .60       .85       .82       .80       .80
       .82       .76       .80       .82       .85       .87       .90       .85
       .70       .25       .02       .03       .08       .10       .30       .65
        .0       .10       .40       .85       .80       .75       .73       .75
       .77       .70       .76       .78       .80       .85       .87       .77
       .50       .05       .02       .04       .10       .20       .50       .70
        .0       .01       .02       .06       .42       .82       .85       .88
       .90       .91       .90       .87       .92       .92       .95       .95
       .93       .89       .90       .55       .10       .02       .02       .02
        .0       .01       .02       .06       .42       .80       .85       .87
       .89       .90       .89       .86       .91       .91       .94       .94
       .93       .88       .91       .10       .04       .02       .02       .03
        .0       .01       .02       .12       .57       .82       .85       .86
       .88       .88       .83       .84       .91       .93       .92       .95
       .88       .90       .60       .10       .03       .02       .03       .05
        .0       .01       .09       .40       .75       .84       .84       .84
       .86       .80       .86       .87       .90       .92       .92       .90
       .85       .56       .15       .04       .04       .05       .10       .25
        .0       .01       .20       .60       .85       .82       .80       .80
       .82       .76       .80       .82       .85       .87       .90       .85
       .70       .25       .02       .03       .08       .10       .30       .65
        .0       .10       .40       .85       .80       .75       .73       .75
       .77       .70       .76       .78       .80       .85       .87       .77
       .50       .05       .02       .04       .10       .20       .50       .70
        .0       .01       .05       .40       .83       .82       .83       .86
       .88       .89       .88       .85       .89       .90       .92       .92
       .90       .86       .40       .02       .02       .02       .02       .05
        .0       .01       .06       .42       .80       .80       .83       .85
       .87       .88       .87       .84       .87       .89       .91       .91
       .90       .85       .39       .02       .04       .05       .10       .20
        .0       .01       .12       .57       .82       .82       .83       .84
       .86       .85       .81       .82       .87       .91       .89       .92
       .85       .77       .37       .02       .06       .10       .20       .40
        .0       .01       .40       .75       .84       .84       .81       .82
       .84       .78       .84       .85       .86       .90       .89       .87
       .82       .53       .23       .02       .08       .15       .40       .65
        .0       .01       .60       .80       .88       .82       .78       .78
       .80       .74       .78       .80       .82       .85       .87       .82
       .67       .10       .02       .02       .10       .25       .65       .70
        .0       .15       .80       .85       .90       .75       .71       .73
       .75       .68       .74       .76       .78       .83       .84       .74
       .48       .02       .02       .02       .12       .30       .70       .75
        16         6         2
       .30       .35       .40       .45       .55       .65       .75       .80
       .85       .90       .95      1.00      1.05      1.10      1.15      1.30
        0.       45.       60.       75.       85.       90.      100.      500.
      .000      .050      .100      .230      .520      .800      .940      .990
      .980      .880      .630      .370      .140      .050      .000      .000
      .000      .049      .099      .228      .514      .792      .931      .980
      .970      .871      .624      .366      .139      .049      .000      .000
      .000      .048      .096      .221      .499      .768      .902      .950
      .941      .845      .605      .355      .134      .048      .000      .000
      .000      .044      .088      .202      .458      .704      .827      .871
      .862      .774      .554      .326      .123      .044      .000      .000
      .000      .038      .075      .173      .390      .600      .705      .743
      .735      .660      .473      .278      .105      .038      .000      .000
      .000      .033      .065      .150      .338      .520      .611      .644
      .637      .572      .410      .241      .091      .033      .000      .000
      .000      .050      .100      .230      .520      .800      .940      .990
      .980      .880      .630      .370      .140      .050      .000      .000
      .000      .049      .099      .228      .514      .792      .931      .980
```

Figure 20.- Data deck - Sample Problem 5.

.970	.871	.624	.366	.139	.049	.000	.000
.000	.048	.096	.221	.499	.768	.902	.950
.941	.845	.605	.355	.134	.048	.000	.000
.000	.044	.088	.202	.458	.704	.827	.871
.862	.774	.554	.326	.123	.044	.000	.000
.000	.038	.075	.173	.390	.600	.705	.743
.735	.660	.473	.278	.105	.038	.000	.000
.000	.033	.065	.150	.338	.520	.611	.644
.637	.572	.410	.241	.091	.033	.000	.000
8	2	5					
.30	.35	.38	.40	.50	.60	1.	1.3
.0	90.	.2	.4	.6	.8	1.	
.0	.0	.0	.0	.0	.0	.0	.0
.0	.0	.0	.0	.0	.0	.0	.0
.005	.005	.016	.009	.014	.004	.0	.0
.005	.005	.016	.009	.014	.004	.0	.0
.008	.008	.024	.015	.021	.005	.0	.0
.008	.008	.024	.015	.021	.005	.0	.0
.02	.018	.048	.029	.040	.012	.001	.001
.02	.018	.048	.029	.040	.012	.001	.001
.12	.11	.39	.23	.345	.085	.015	.01
.12	.11	.39	.23	.345	.085	.015	.01
4	2	4					
.3	.8	1.1	1.3	.0	90.	.2	.4
.6	1.						
.0	.0	.0	.0	.0	.0	.0	.0
.002	.01	.002	.002	.002	.01	.002	.002
.004	.02	.006	.004	.004	.02	.006	.004
.006	.03	.01	.007	.006	.03	.01	.007

Figure 20.- Concluded.

```
INPUT DATA      RUN 5               SAMPLE PROBLEM 5 - COMPLETE MISSION ANALYSIS


          NAU=  4
       NTHETA=  9
        KPLOT=  0
         KOUT=  0
         AREA=  0.20000000E 01
         TREF=  0.30300000E 03
         VREF=  0.59400000E 03
         IREF=  0.0
        XJLTR=  0.53299999E 00
          ATX=  0.34999987E-03
          BRS=  0.20000000E 01
           RS=  0.10999995E 00


ABSOLUTE RESPONSE/RELATIVE RESPONSE =   0.53300
```

Figure 21.- Output - Sample Problem 5.

10/21/70

SOLAR CELL PERFORMANCE
RUN 5

SAMPLE PROBLEM 5 - COMPLETE MISSION ANALYSIS

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=-1.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (COMPLETE ARRAY)

AU = 1.0000 TC = 285.0000

NIS = 4.00 VIS = 54.00 SCL = 0.50000000E 00

THETAS =	5.00	15.00	25.00	35.00	45.00
THETAS =	55.00	65.00	75.00	85.00	
FTHETAS =	2.67	2.67	2.67	2.67	2.67
FTHETAS =	2.67	2.67	2.67	2.67	

I	CURRENT(AMPS)	VOLTAGE(VOLTS)
1	0.26333208E 01	0.0
2	0.26333219E 01	0.10000000E 01
3	0.26333218E 01	0.20000000E 01
4	0.26333227E 01	0.30000000E 01
5	0.26333227E 01	0.40000000E 01
6	0.26333208E 01	0.50000000E 01
7	0.26333189E 01	0.60000000E 01
8	0.26333094E 01	0.70000000E 01
9	0.26332941E 01	0.80000000E 01
10	0.26332684E 01	0.90000000E 01
11	0.26332216E 01	0.10000000E 02
12	0.26331406E 01	0.11000000E 02
13	0.26326895E 01	0.12000000E 02
14	0.26325750E 01	0.13000000E 02
15	0.26320333E 01	0.14000000E 02
16	0.26313410E 01	0.15000000E 02
17	0.26303644E 01	0.16000000E 02
18	0.26289206E 01	0.17000000E 02
19	0.26268940E 01	0.18000000E 02
20	0.26238489E 01	0.19000000E 02
21	0.26193838E 01	0.20000000E 02
22	0.26129723E 01	0.21000000E 02
23	0.26036835E 01	0.22000000E 02
24	0.25899706E 01	0.23000000E 02
25	0.25702677E 01	0.24000000E 02
26	0.25412750E 01	0.25000000E 02
27	0.24996090E 01	0.26000000E 02
28	0.24388313E 01	0.27000000E 02
29	0.23506231E 01	0.28000000E 02
30	0.22227736E 01	0.29000000E 02
31	0.20380917E 01	0.30000000E 02
32	0.17725830E 01	0.31000000E 02
33	0.13924150E 01	0.32000000E 02
34	0.85285771E 00	0.33000000E 02
35	0.13250685E 00	0.34000000E 02

I(PMAX) = 0.24027452E 01 V(PMAX) = 0.27464981E 02 P(MAX) = 0.65998932E 02

Figure 21.- Continued.

SOLAR CELL PERFORMANCE
RUN 5

SAMPLE PROBLEM 5 - COMPLETE MISSION ANALYSIS

FIXED CELL CHARACTERISTICS

AREA= 2.00 VREF=594.0 IREF=-1.00 ATX= 0.000350 BRS= 2.00 RS= 0.11

ENVIRONMENTAL CELL PERFORMANCE - (COMPLETE ARRAY)

AU = 0.8000 TC = 320.0000

NIS = 4.00 VIS = 54.00 SCL = 0.50000000E 00

THETAS =	5.00	15.00	25.00	35.00	45.00
THETAS =	55.00	65.00	75.00	85.00	
FTHETAS =	2.67	2.67	2.67	2.67	2.67
FTHETAS =	2.67	2.67	2.67	2.67	

I	CURRENT(AMPS)	VOLTAGE(VOLTS)
1	0.46846695E 01	0.0
2	0.46846685E 01	0.10000000E 01
3	0.46846704E 01	0.20000000E 01
4	0.46846695E 01	0.30000000E 01
5	0.46846695E 01	0.40000000E 01
6	0.46846342E 01	0.50000000E 01
7	0.46841526E 01	0.60000000E 01
8	0.46838417E 01	0.70000000E 01
9	0.46833105E 01	0.80000000E 01
10	0.46824923E 01	0.90000000E 01
11	0.46814237E 01	0.10000000E 02
12	0.46799593E 01	0.11000000E 02
13	0.46777859E 01	0.12000000E 02
14	0.46746655E 01	0.13000000E 02
15	0.46704655E 01	0.14000000E 02
16	0.46640615E 01	0.15000000E 02
17	0.46553240E 01	0.16000000E 02
18	0.46425228E 01	0.17000000E 02
19	0.46248856E 01	0.18000000E 02
20	0.45990238E 01	0.19000000E 02
21	0.45631227E 01	0.20000000E 02
22	0.45116863E 01	0.21000000E 02
23	0.44390297E 01	0.22000000E 02
24	0.43361969E 01	0.23000000E 02
25	0.41905222E 01	0.24000000E 02
26	0.39851522E 01	0.25000000E 02
27	0.36964922E 01	0.26000000E 02
28	0.32929411E 01	0.27000000E 02
29	0.27335272E 01	0.28000000E 02
30	0.19642057E 01	0.29000000E 02
31	0.92195213E 00	0.30000000E 02

I(PMAX) = 0.41957083E 01 V(PMAX) = 0.23970291E 02 P(MAX) = 0.10057326E 03

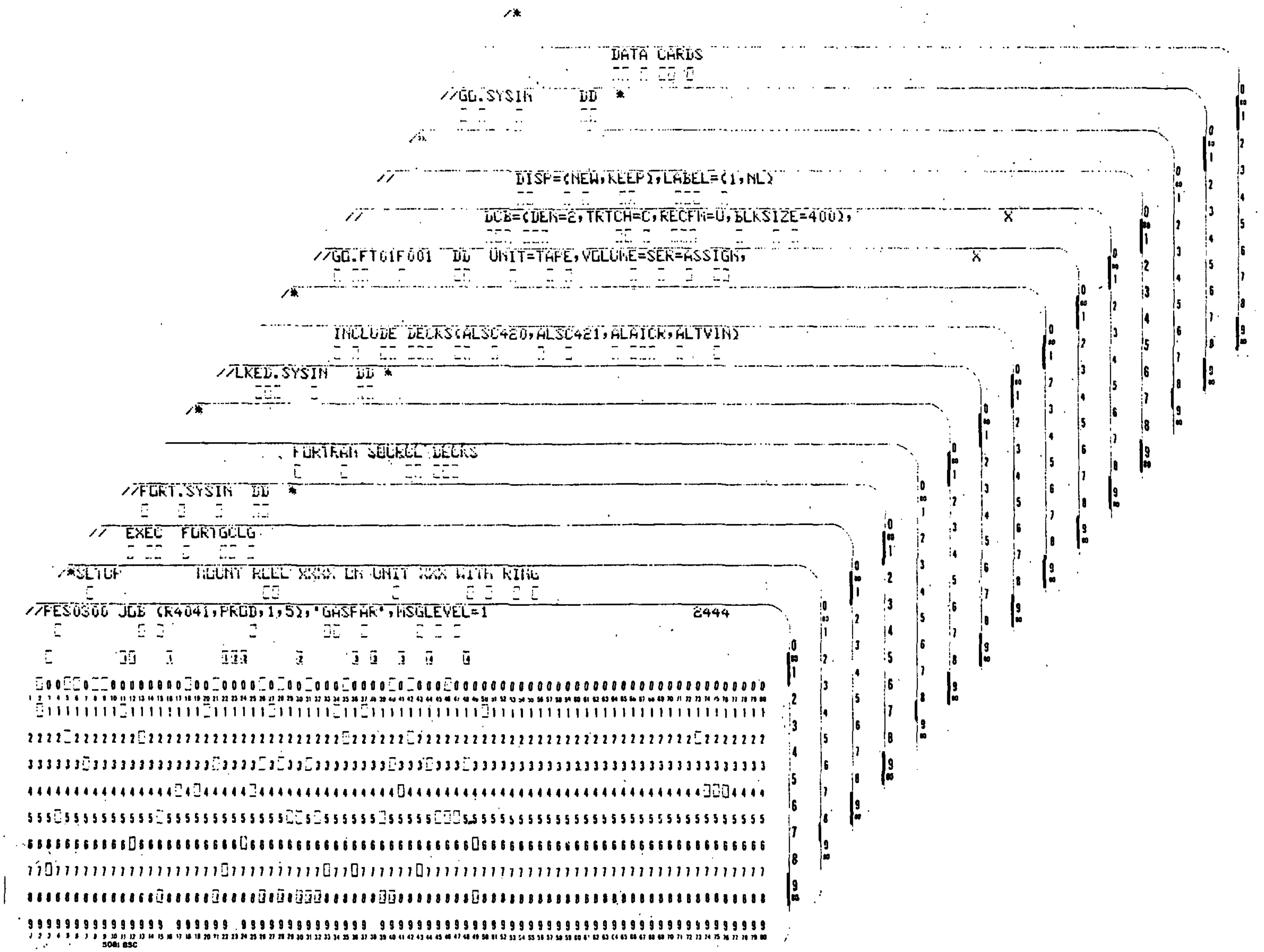
NOTE: Similar data for 0.6 and 0.4 AU are printed but have been eliminated in this figure.

Figure 21.- Concluded.

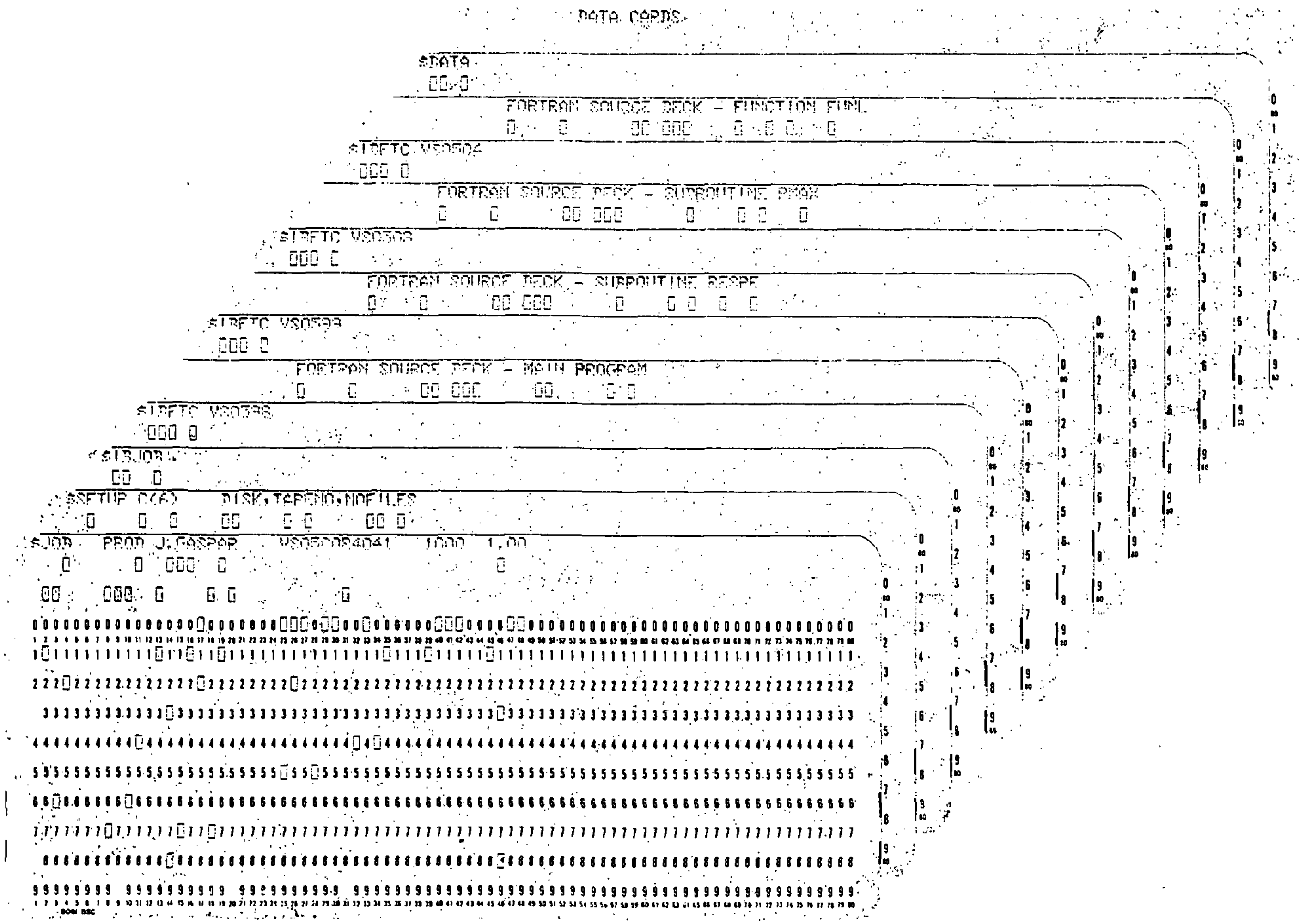
APPENDIX B

DESCRIPTION OF DATA CARD INPUT

Control Cards for 360/67 Version



Control Cards for 7094 Version



MAIN PROGRAM				
Card number	Variable name	Columns	Format	Description of variables
1	R(1)	1-6	A6	Run number
	R(1), R(2)	1-8	2A4[a]	
2	TITLE	1-72	12A6(18A4)[a]	Run identification
3	NAU	1-10	8I10	Number of variables in AU, T, A, and VCL arrays
	NTHETA	11-20		Number of variables in THETA and FTHETA arrays
	KPLOT	21-30		1 = plot (S-C 4020) 0 = omit plot
	KOUT	31-40		1 = detailed single-cell output 0 = no single-cell output
	INT	41-50		Input code for transmission table = 0 Omit = 1 Singularly variant (use TAINT) = 2 Bivariant (use TVIN) = 3 Trivariant (use TVIN)
	INR	51-60		Input code for response table (same as INT)
	INTD	61-70		Input code for transmission damage table (same as INT)
	INRD	71-80		Input code for response damage table (same as INT)
4[b]	AU	1-10,etc.	8F10.4	Solar distance, AU
5[b]	T	1-10,etc.	8F10.4	Temperature, °K
6[b]	A	1-10,etc.	8F10.4	Curve factor used in diode equation (eq. (6))
7[b]	VCL	1-10,etc.	8F10.4	Current coefficient used in open circuit voltage equation (eq. 5)), mV/mA
8	AREA	1-10	8F10.4	Single-cell surface area, cm^2
	TREF	11-20		Reference temperature, °K
	VREF	21-30		Reference voltage, mV
	IREF	31-40		Reference current (AMZ), mA

[a]Format for IBM 360/67.
[b]Eight values per card; number of cards depends on NAU.

Card number	Variable name	Columns	Format	Description of variable

8	XJLTR	41-50		If (INT + INR) = 0
				$\neq 0$ Conversion constant used in equation (1) in A/mW
				= 0 Compute XJLTR from equation (2)
				If (INT + INR) $\neq$ 0
				$\neq$ -1 Set CONST = XJLTR and solve equation (3)
				= -1 Calculate CONST from equation (4) and then solve equation (3) for XJLTR

	ATX	51-60		Temperature coefficient in current density equation (eq. 2)), $\Delta I/I$ per °K
	BRS	61-70		Temperature coefficient in open circuit voltage equation (eq. (5)), mV/°K
	RS	71-80		Cell series resistance, Ω
9[c]	THETA	1-10,etc.	8F10.4	Solar incidence angles, deg
10[c]	FTHETA	1-10,etc.	8F10.4	Number of strings at angular orientation THETA
11	NIS	1-10	8F10.4	Number of cells in a parallel group
	VIS	11-20		Number of parallel groups wired in series to form a string
	SCL	21-30		String circuit loss, V
12[d]	PLOT	14-20		Date
	INFORMATION	25-32		Name
		34-37		Installation
		40-42		Building number
SUBROUTINE RESPE				
Transmission table (required only if INT $\neq$ 0)				
13	KWAVE	1-10	3I10	Number of wavelength variables
	KTHET	11-20		Number of incidence angle variables
	KTEMP	21-30		Number of temperature variables
14[e]	XTAB	1-10	8F10.4	Array of wavelengths, angles, and temperatures. Array size is KWAVE + KTHET + KTEMP
15[e]	WTAB	1-10 11-20,etc.	8F10.4	Transmission values corresponding to XTAB. Array size is KWAVE*KTHET*KTEMP

[c]Eight values per card; number of cards depends on NTHETA.
[d]Only if KPLOT = 1.
[e]Number of cards depends on array size. See description of Subroutine AL TVIN in appendix E.

Card number	Variable name	Columns	Format	Description of variable
Response tables (required only if INR ≠ 0)				
16	MWAVE	1-10	3I10	Number of wavelength variables
	MTHET	11-20		Number of incidence angle variables
	MTEMP	21-30		Number of temperature variables
17[e]	XTAB2	1-10,etc.	8F10.4	Array of wavelengths, angles, and temperatures. Array size is MWAVE + MTHET + MTEMP
18[e]	WTAB2	1-10,etc.	8F10.4	Response values corresponding to XTAB2. Array size is MWAVE*MTHET*MTEMP
Transmission damage tables (required only if INTD ≠ 0)				
19	LWAVE	1-10	3I10	Number of wavelength variables
	LTHET	11-20		Number of incidence angle variables
	LAU	21-30		Number of AU variables
20[e]	XTAB1	1-10,etc.	8F10.4	Array of wavelengths, angles, and AU's. Array size is LWAVE + LTHET + LAU
21[e]	WTAB1	1-10,etc.	8F10.4	Transmission damage values corresponding to XTAB1. Array size is LWAVE*LTHET*LAU
Response damage tables (required only if INRD ≠ 0)				
22	JWAVE	1-10		Number of wavelength variables
	JTHET	11-20		Number of incidence angle variables
	JAU	21-30		Number of AU variables
23[e]	XTAB3	1-10,etc.		Array of wavelengths, angles, and AU's. Array size is JWAVE + JTHET + JAU
24[e]	WTAB3	1-10,etc.		Response damage values corresponding to XTAB3. Array size is JWAVE*JTHET*JAU

[e]Number of cards depends on array size. See description of Subroutine AL TVIN in appendix E.

APPENDIX C

PROGRAM SYMBOL LIST

Main Program

Variable	Description
A	curve factor used in equations (6) and (7)
AA	single value in A array
ABC ABSC	plotting titles for the X-axis
AREA	single solar cell surface area
ATX	temperature coefficient in equation (1)
AU	solar distance in astronomical units
AUC	single value in the AU array
BL	lower bound on X in subroutine AL ROOT
BU	upper bound on X in subroutine AL ROOT
BRS	temperature coefficient in equation (5)
DENOM	denominator of equation (6)
DMON 1 DMON 2 DMON 3 DMON 4 DMON 5 DMON 6	variables used by AL TAINT which must be set to zero initially and whenever the argument array is altered
E1 E2	numbers that specify the degree of precision expected of the root determination (AL ROOT)
EO	equals E1
ET	equals E2
FMAX	interpolation variable used in subroutine PMAX

Variable	Description
FTHETA	number of strings at each orientation (eq. (10))
FUNC	product of current and voltage in subroutine PMAX
GS	initial guess (AL ROOT)
II	number of voltage and current pairs used to describe I-V curve
I	see ILOAD, SCURR
ILOAD	current at a given voltage (equivalent to I in equations (6) and (8))
IL	light generated current
INR	input code for response tables
INRD	input code for response damage tables
INT	input code for transmission tables
INTD	input code for transmission damage tables
IO	reverse saturation current (eq. (6))
IREF	reference short circuit current (eq. (2))
JCDREF	factor used in computing XJLTR
JCD	short circuit current density (eq. (1))
KINT	sum of table input codes used to regulate use of subroutine RESPE
KOUT	input code regulating detailed output
KPLOT	input code regulating plotting
KSV	counter used in array calculations
KT	constant used by subroutine RESPE to determine if tables should be read
LAST	variable to test end of data
NAU	size of AU array
NER	error code (AL TAINT)

Variable	Description
NIS	number of cells connected in parallel (eq. (8))
NRR	error code (AL TAINT, AL ROOT)
NSV	counter used in array calculations
NTHETA	size of NTHETA and FTHETA arrays
ORD 1 ORD 2 ORD 3 ORD 4	plotting titles for y-axis
PILOAD	ILOAD * (-1.0)
PI	π, 3.1415927
PSP	specific power (power/area)
PVOLTM	not used
PWRMAX	maximum power
R	array containing title for each run
RS	series resistance (eq. (6))
SCL	string circuit loss (eq. (9))
SCURR	string current variables (equivalent to I in eq. (10))
SFUNC	string current x voltage
SI	variable used in string current calculations
SMAX	current at maximum power
SVOLT	string voltages (equivalent to V in eq. (11))
T	solar cell operating temperature
TC	single variable in T array
THETA	solar incidence angles in degrees
TITLE	title for printer output

Variable	Description
TREF	reference temperature (eq. (1))
V	see VOLTM, SVOLT
VCL	current coefficient (eq. (5))
VIS	number of cells connected in series (eq. (9))
VOC	open circuit voltage (eq. (5))
VOLTM	voltage variable used in obtaining I-V curve from equation (6) (equivalent to V in eqs. (6) and (9))
VREF	reference voltage (eq. (5))
XJLTR	conversion constant (eq. (1))
XL	lower limit of x-axis for plotting
XMAX	voltage at maximum power
XU	upper limit of x-axis for plotting
YL	lower limit of y-axis for plotting
YU	upper limit of y-axis for plotting

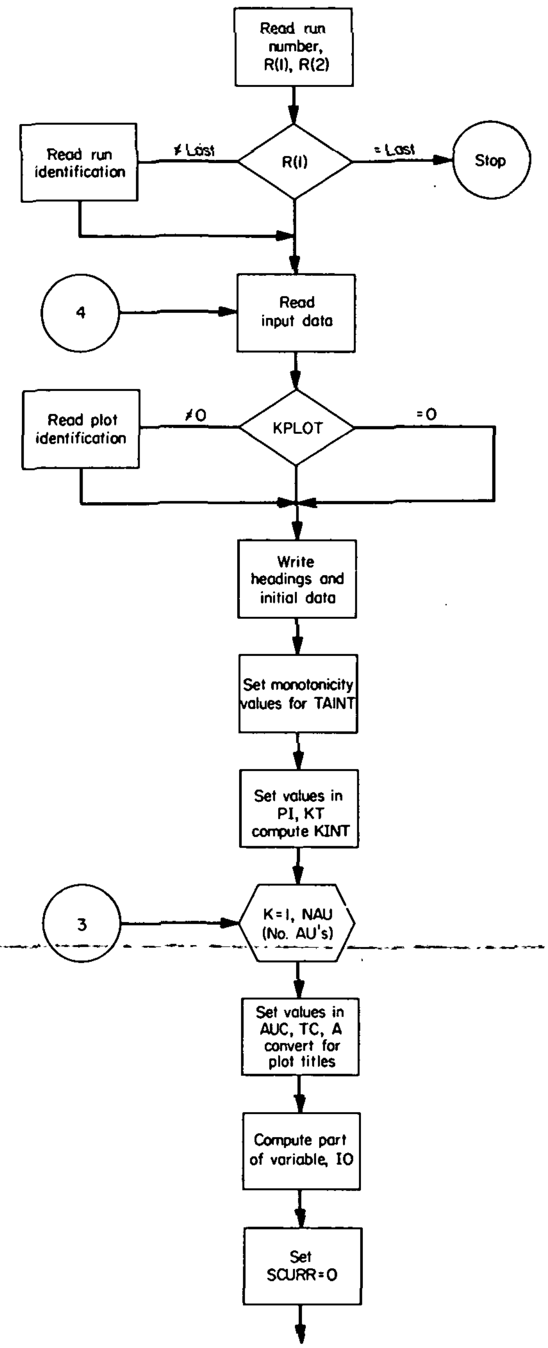
Subroutine RESPE

CONST	proportionality factor in equation (3)
DMON DMON 1 DMON 2 DMON 3	variable used by AL TAINT which must be set to zero initially and whenever the argument array is altered
DRESP	response damage corresponding to a specific wavelength (eq. (3))
DTRANS	transmission damage corresponding to a specific wavelength (eq. (3))
FACTOR	variable used in calculation of XJLTR
IERR	error code from (AL TVIN)
JAU	number of solar variables in response damage tables

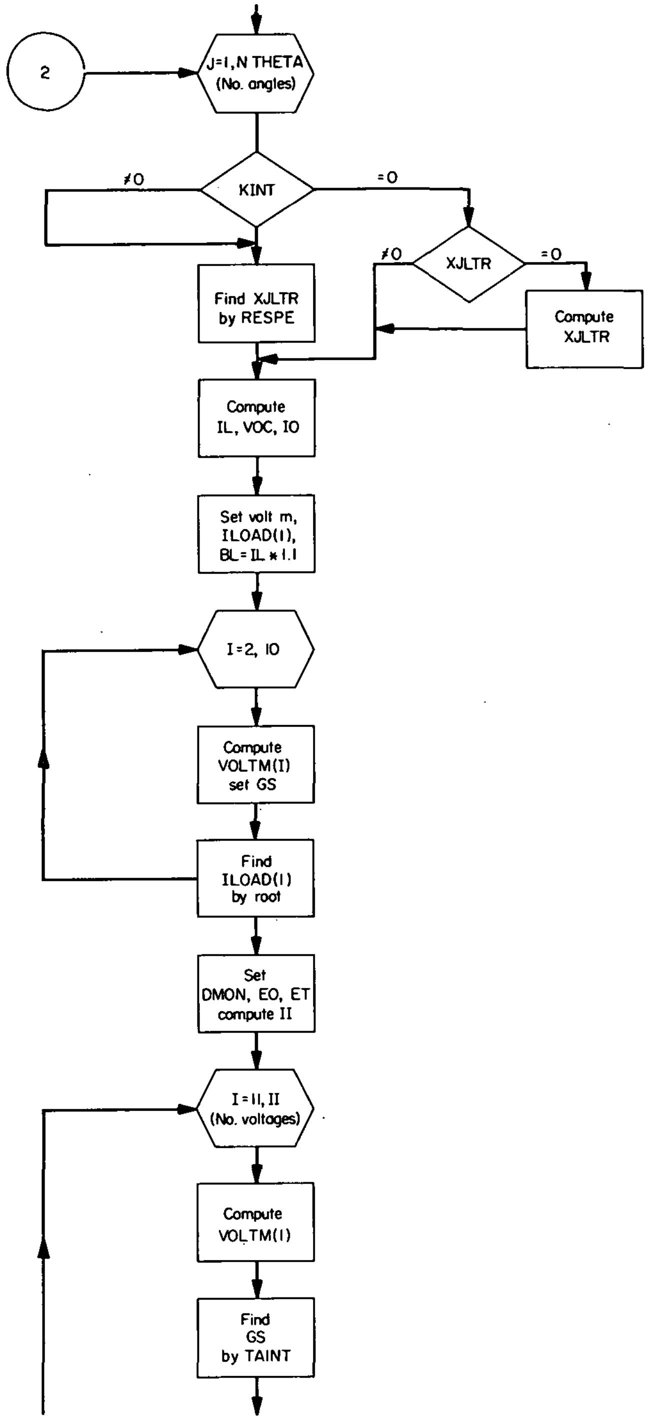
Variable	Description
JTHET	number of incidence angle variables in response damage tables
JWAVE	number of wavelength variables in response damage tables
K1	number of variables in transmission array (TINV)
K2	number of variables in transmission damage array (TDINV)
K3	number of variables in response array (RINV)
K4	number of variables in response damage array (RDINV)
KTEMP	number of temperature variables in transmission tables
KTHET	number of incidence angle variables in transmission tables
KWAVE	number of wavelength variables in transmission tables
LAU	number of solar distance variables in transmission damage tables
LREF	source spectral energy distribution used in equation (4)
LSOLAR	solar spectral energy distribution (L_λ) used in equation (3)
LTHET	number of incidence angle variables in transmission damage tables
LWAVE	number of wavelength variables in transmission damage tables
MTEMP	number of temperature variables in response tables
MTHET	number of incidence angle variables in response tables
MWAVE	number of wavelength variables in response tables
NER	error code (AL TAINT)
NP	number of variables in the RWAVE and LREF data statements
NW	number of variables in the WAVE and LSOLAR data statements
NW 1	number of variables in the transmission array (TARG)
NW 2	number of variables in the transmission damage array (TDARG)
NW 3	number of variables in the response array (RARG)

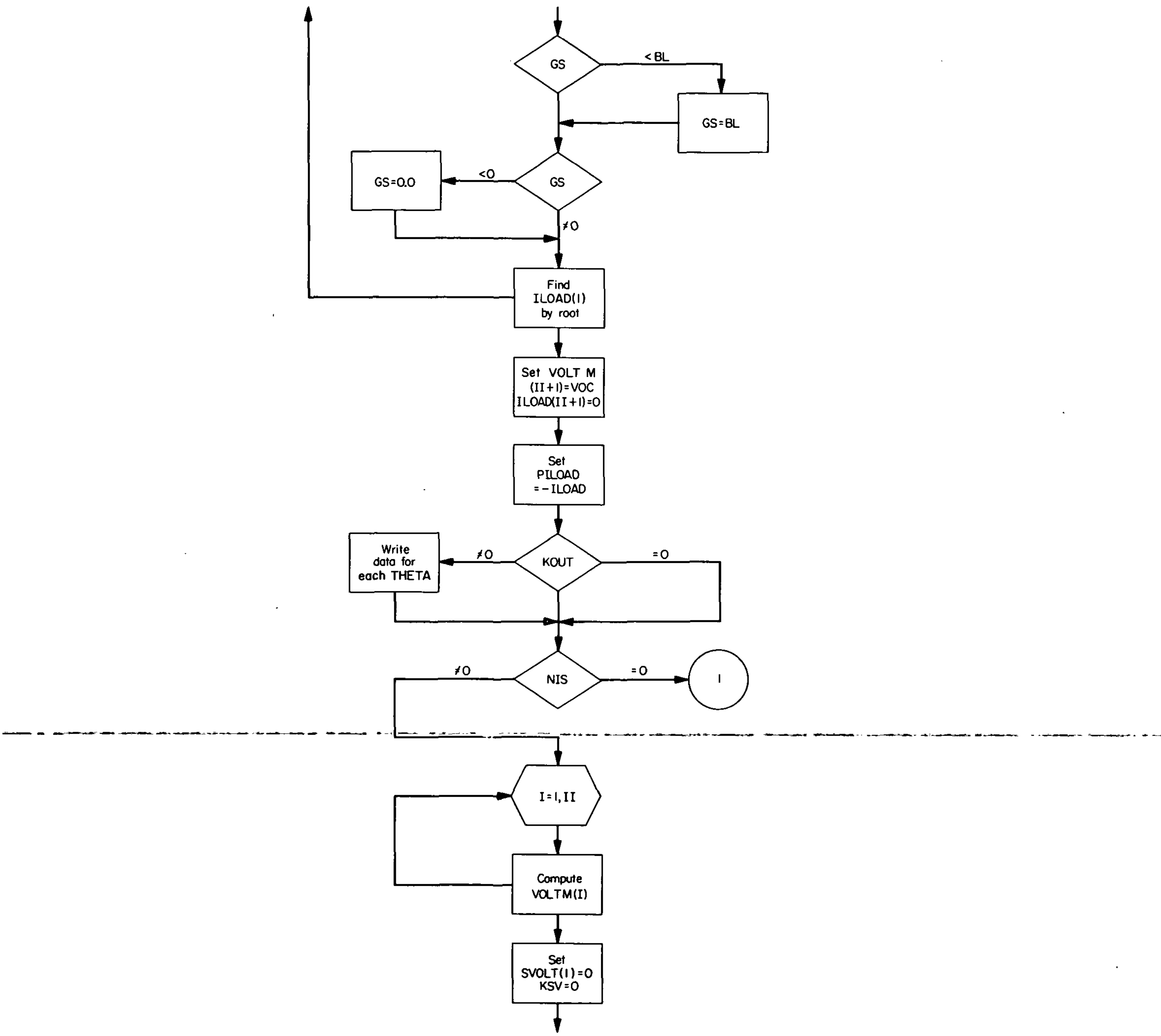
Variable	Description
NW 4	number of variables in the response damage array (RDARG)
NXYZ	array containing the number of wavelengths, angles, and temperatures in TINV table
NXYZ 1	array containing the number of wavelengths, angles, and temperatures in TDINV table
NXYZ 2	array containing the number of wavelengths, angles, and temperatures in RINV table
NXYZ 3	array containing the number of wavelengths, angles, and temperatures in RDINV table
RARG	array of response values corresponding to RINV table
RDARG	array of response damage values corresponding to RDINV table
RDINV	array of wavelengths or wavelengths, angles, and temperatures for response damage
RESP	response variable corresponding to a wavelength as a result of table look-up
RINV	array of wavelengths or wavelengths, angles, and temperatures for response
RWAVE	array of wavelengths corresponding to LREF array (eq. (4))
SUM	variable used in computing XJLTR
TARG	array of transmission values corresponding to TINV table
TDARG	array of transmission damage values corresponding to TDINV table for transmission
TDINV	array of wavelengths or wavelengths, angles, and temperatures for transmission damage
TINV	array of wavelengths or wavelengths, angles, and temperatures for transmission
TIRR	constant used to compute CONST
TRANS	transmission variable
WAVE	array of wavelengths corresponding to LSOLAR (eq. (3))

Variable	Description
XYZ	array of wavelength, angle, and temperature arguments for table look-up for transmission
XYZ 1	array of wavelength, angle, and temperature arguments for table look-up for transmission damage
XYZ 2	array of wavelength, angle, and temperature arguments for table look-up for response
XYZ 3	array of wavelength, angle, and temperature arguments for table look-up for response damage

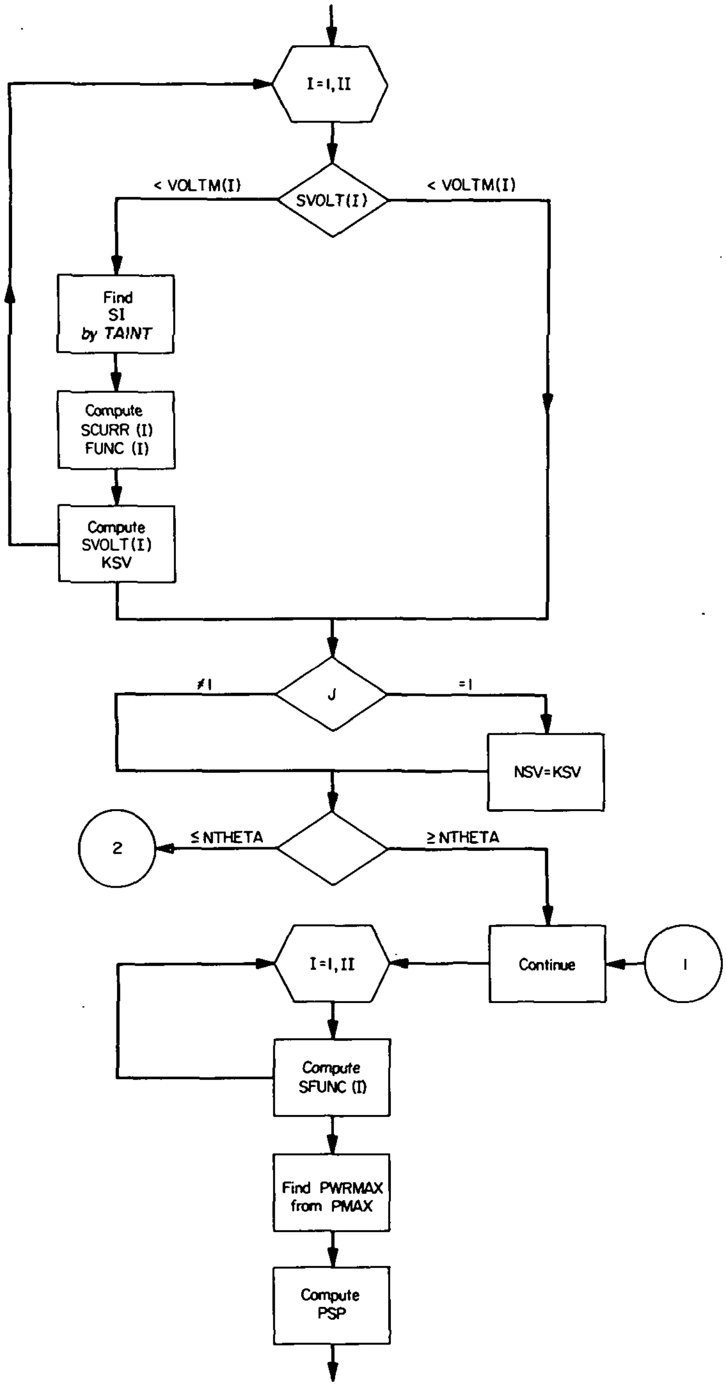


Read run number, R(1), R(2)
R(1)
≠ Last
= Last
Read run identification
Stop
4
Read input data
KPLOT
≠0
=0
Read plot identification
Write headings and initial data
Set monotonicity values for TAINT
Set values in PI, KT compute KINT
3
K=1, NAU (No. AU's)
Set values in AUC, TC, A convert for plot titles
Compute part of variable, IO
Set SCURR=0

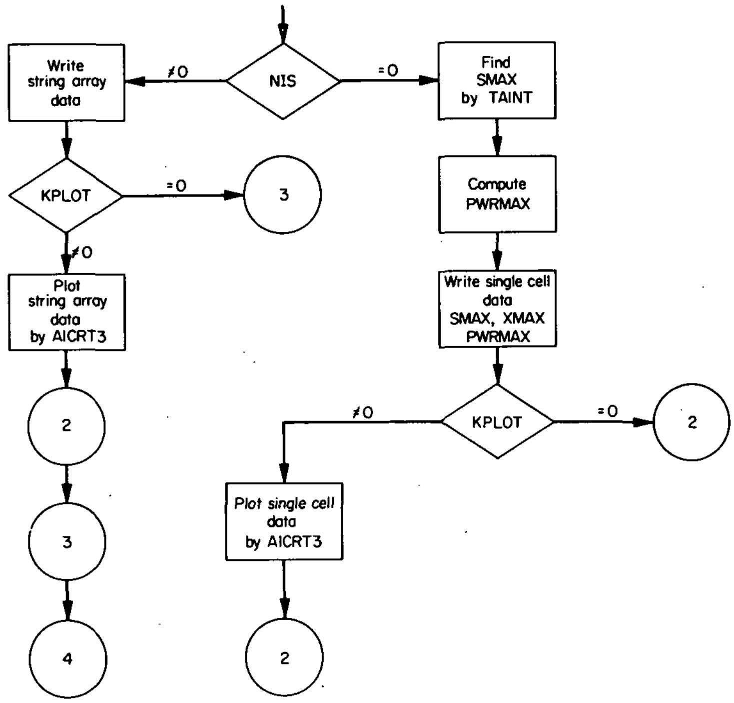

2
J=1,N THETA (No. angles)
KINT
≠0
=0
XJLTR
≠0
=0
Find XJLTR by RESPE
Compute XJLTR
Compute IL, VOC, IO
Set volt m, ILOAD(1), BL=IL*1.1
I=2, 10
Compute VOLTM(I) set GS
Find ILOAD(I) by root
Set DMON, EO, ET compute II
I=11, II (No. voltages)
Compute VOLTM(I)
Find GS by TAINT

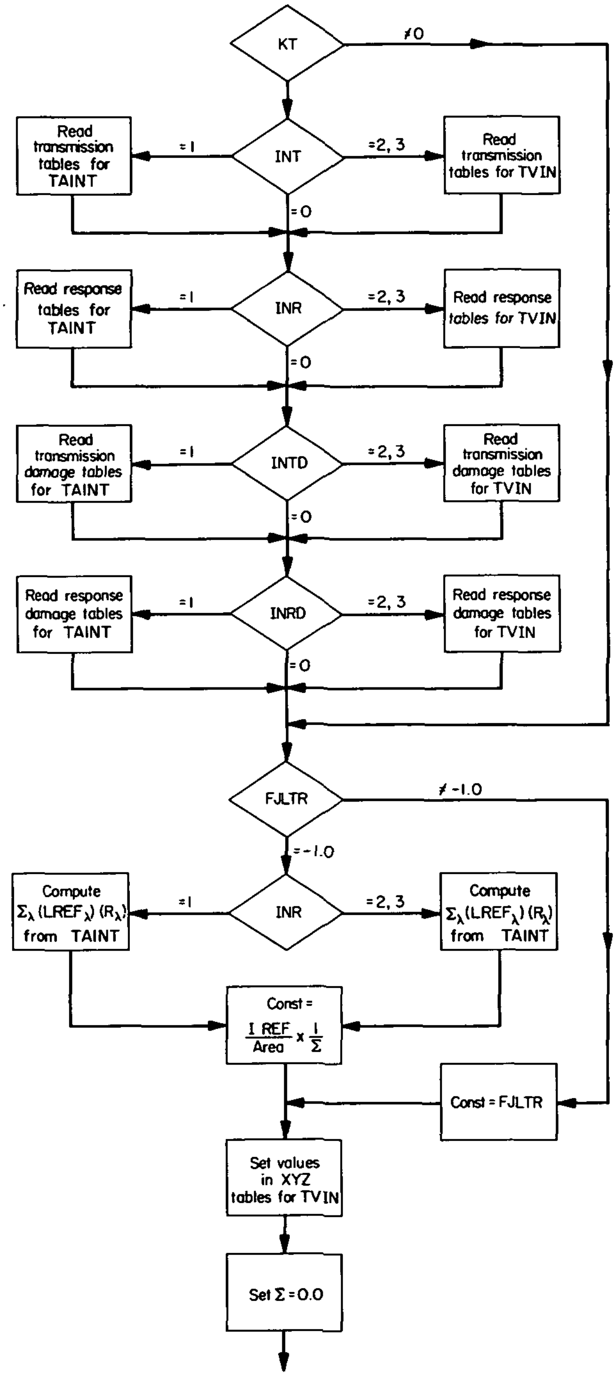


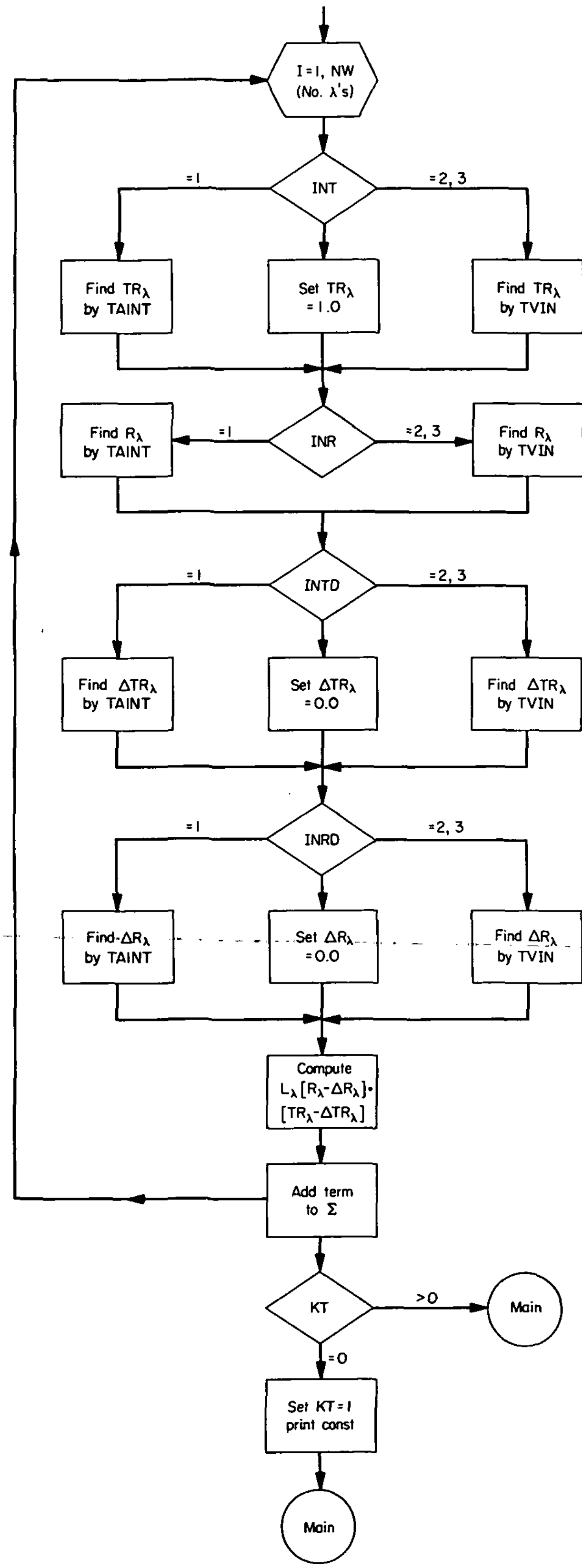
GS
< BL
GS=BL
GS=0.0
<0
GS
≠0
Find ILOAD(I) by root
Set VOLT M (II+1)=VOC ILOAD(II+1)=0
Set PILOAD =-ILOAD
Write data for each THETA
≠0
KOUT
=0
≠0
NIS
=0
I
I=1,II
Compute VOLTM(I)
Set SVOLT(I)=0 KSV=0



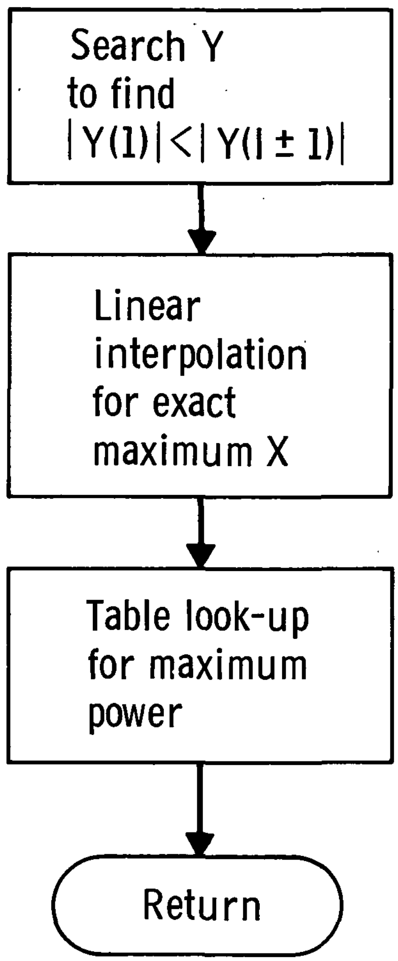
I=1,II
< VOLTM(I)
SVOLT(I)
< VOLTM(I)
Find
SI
by TAINT
Compute
SCURR (I)
FUNC (I)
Compute
SVOLT(I)
KSV
≠1
J
=1
NSV=KSV
2
≤ NTHETA
≥ NTHETA
I=1,II
Continue
1
Compute
SFUNC (I)
Find PWRMAX
from PMAX
Compute
PSP


NIS
≠0
=0
Write
string array
data
Find
SMAX
by TAINT
KPLOT
=0
3
Compute
PWRMAX
≠0
Plot
string array
data
by AICRT3
Write single cell
data
SMAX, XMAX
PWRMAX
2
≠0
KPLOT
=0
2
3
Plot single cell
data
by AICRT3
4
2


KT
≠0
Read transmission tables for TAINT
=1
INT
=2, 3
Read transmission tables for TVIN
=0
Read response tables for TAINT
=1
INR
=2, 3
Read response tables for TVIN
=0
Read transmission damage tables for TAINT
=1
INTD
=2, 3
Read transmission damage tables for TVIN
=0
Read response damage tables for TAINT
=1
INRD
=2, 3
Read response damage tables for TVIN
=0
FJLTR
≠ -1.0
= -1.0
Compute $\Sigma_\lambda (LREF_\lambda)(R_\lambda)$ from TAINT
=1
INR
=2, 3
Compute $\Sigma_\lambda (LREF_\lambda)(R_\lambda)$ from TAINT
Const = $\frac{I\ REF}{Area} \times \frac{1}{\Sigma}$
Const = FJLTR
Set values in XYZ tables for TVIN
Set Σ = 0.0


I = I, NW
(No. λ's)
INT
=I
=2, 3
Find TRλ by TAINT
Set TRλ = I.0
Find TRλ by TVIN
INR
=I
=2, 3
Find Rλ by TAINT
Find Rλ by TVIN
INTD
=I
=2, 3
Find ΔTRλ by TAINT
Set ΔTRλ =0.0
Find ΔTRλ by TVIN
INRD
=I
=2, 3
Find ΔRλ by TAINT
Set ΔRλ =0.0
Find ΔRλ by TVIN
Compute Lλ [Rλ-ΔRλ]• [TRλ-ΔTRλ]
Add term to Σ
KT
>0
Main
=0
Set KT=I print const
Main

SUBROUTINE PMAX



APPENDIX E

PROGRAMMER'S INFORMATION

The program is coded in FORTRAN IV in two versions. One version is designed to run on an IBM 7094 computer with optional graphical output on an SC-4020 plotter. The decks were compiled and the program was validated on the IBM 7094 computer under the IBJOB processor using the IBSYS operating system, version 13. The second version is designed to run on an IBM 360/67 computer, with optional graphical output on an SC-4020 plotter. These decks were compiled on an IBM 360/67, using Release 17, FORTRAN H with OPT = 2 and the program was validated on an IBM 360/67 computer using OS, Release 17.

The program should operate with only minor changes in control cards in either compiler. The amount of core available on the IBM 7094 computer was 32,768 words. On the IBM 360/67 computer 158,000 bytes of core was available.

If a SC-4020 plotter is not available, the IBM 7094 version of the program may be altered as follows:

1. Omit these cards

   EXTERNAL SYSACC

   IF (KPLOT. EQ. O) GO TO 2

   CALL READIN (SYSACC)

   50 CALL EOFTV

2. Change

   CALL EXIT

   to

   50 CALL EXIT

3. Omit data card supplied for CALL READIN

4. Substitute a dummy subroutine for AL AICR

The IBM 360/67 version of the program should be altered in the following manner:

1. Omit these cards

   IF (KPLOT. EQ. O) GØ TO 2

   CALL READIN (SYSACC)

2. Change

   5000 CALL EØFTV

   to

   5000 STOP

3. Omit data card supplied for

   CALL READIN

4. Substitute a dummy subroutine for AL AICR

APPENDIX F

PROGRAM AND SUBROUTINES

```
C         SOLAR CELL PERFORMANCE PROGRAM - KIRKPATRICK
C
C         GENERAL PURPOSE
C
      EXTERNAL FUNL
      EXTERNAL SYSACC
      EQUIVALENCE (FIRST,FIRST)
      FIRST=1.0
      REAL NIS,ISC,IREF,JCDREF
      REAL JCD,IL,IO,ILOAD,LAST
      COMMON/COM/VOLTM(95),I,RS,DENOM,IO,IL,C7,II,FUNC(50),SVOLT(50),NSV
     1,DMON4,NIS,SFUNC(95),DMON6
      COMMON/COM1/AREA,IREF,TREF,INT,INR,INTD,INRD
      DIMENSION THETA(10),AU(10),T(10),R(6),ABSC(9),ORD1(9),ORD2(9),
     1ORD3(9),ORD4(9),ABC(9)
      DIMENSION  PVOLTM(95),ILOAD(95),PILOAD(95), A(15),RR(2),SCURR(50),
     1VCL(10),FTHETA(10),TITLE(12),LAST(2)
      EQUIVALENCE (VOLTM,PVOLTM)
      DATA RR(2)/3H   /
      DATA R(2),R(3),R(5)/3HRS=, 6H  AU =,6H  TC =/
      DATA FMT1,FMT3,FMT4/6H(F4.2),6H(F5.1),4H(A6)/
      DATA (ABSC(I),I=1,9)/6H       ,6H      ,6H    VO,6HLTAGE ,6H (VOLT,
     16HS)    ,6H      ,6H      /
      DATA (ABC(I),I=1,9)/6H       ,6H      ,6H    V, 6HOLTAGE,6H (MILL,
     16HIVOLTS,6H)     ,6H      /
      DATA (ORD1(I),I=1,9)/6H      ,6H      ,6H      ,6H     C,6HURRENT,
     16H(AMPS),6H      ,6H      /
      DATA (ORD2(I),I=1,9)/6H      ,6H      ,6H      ,6HPOWER(,6HMICROW,
     16HATTS) ,6H      ,6H      /
      DATA (ORD3(I),I=1,9)/6H      ,6H      ,6H      ,6H   POW,6HER(WAT,
     16HTTS)  ,6H      ,6H      /
      DATA (ORD4(I),I=1,9)/6H      ,6H      ,6H      ,6HCURREN,6HT (MIL,
     16HLIAMPS,6H)     ,6H      /
      DATA E1,E2,BU/0.01,0.0001,0.0/
      DATA LAST/6HLAST  /
    1 READ (5,100) R(1)
  100 FORMAT(A6)
      IF(R(1).EQ.LAST) GO TO 50
      READ (5,101) (TITLE(I),I=1,12)
  101 FORMAT(12A6)
C
C          KPLOT = 0  SKIP PLOTTING
C          KPLOT = 1  PLOT
C          KOUT = 0  SKIP  DETAILED OUTPUT FOR CURRENT VS VOLTAGE (THETA)
C          KOUT = 1  PRINT DETAILED OUTPUT FOR CURRENT VS VOLTAGE (THETA)
```

```
      READ (5,103) NAU,NTHETA,KPLOT,KOUT,INT,INR,INTD,INRD
  103 FORMAT(8I10)
      READ (5,102) (AU(I),I=1,NAU)
      READ (5,102) (T(I),I=1,NAU)
      READ (5,102)  (A(I),I=1,NAU)
      READ (5,102) (VCL(I),I=1,NAU)
      READ (5,102) AREA,TREF,VREF,IREF,XJLTR,ATX,BRS,RS
      READ (5,102) (THETA(I),I=1,NTHETA)
      READ (5,102)(FTHETA(I),I=1,NTHETA)
      READ (5,102) NIS,VIS,SCL
  102 FORMAT(8F10.4)
      IF(KPLOT.EQ.0)  GO TO 2
      CALL READIN(SYSACC)
    2 WRITE (6,221) R(1) ,(TITLE(I),I=1,12)
  221 FORMAT(1H1,10X,10HINPUT DATA,10X,A6,10X,12A6///)
      WRITE (6,220) NAU,NTHETA,KPLOT,KOUT,          AREA,TREF,VREF,IREF,
     1XJLTR,ATX,BRS,RS
  220 FORMAT(1H ,10X,7H   NAU=I3/11X,7HNTHETA=,I3/11X,7H KPLOT=,I3/
     111X,7H  KOUT=,I3/11X,7H  AREA=,E
     215.8/11X,7H  TREF=,E15.8/11X,7H  VREF=,E15.8/11X,7H  IREF=,E15.8/
     3  11X,7H XJLTR=,E15.8/11X,7H   ATX=,E15.8/11X,7H   BRS=,E15.8/11X,
     47H    RS=,E15.8)
    5 DMON=0.0
      DMON1=0.0
      DMON2=0.0
      DMON3=0.0
      DMON4=0.0
      DMON5=0.0
      DMON6=0.0
      PI=3.1415927
      KT=0
      KINT = INT & INR & INTD & INRD
      RR(1) = R(2)
      CALL CVRT(RS,1,6H(F4.2),RR(2),1,4H(A3))
      CALL CVRT(RR,2,7H(A3,A3),R(2),1,4H(A6))
      DO 52 K=1,NAU
    6 AUC=AU(K)
      CALL CVRT(AUC,1,FMT1,R(4),1,FMT4)
   11 TC=T(K)
      CALL CVRT(TC,1,FMT3,R(6),1,FMT4)
      AA= A(K)
      DENOM=1000.*AA*TC*1.38E-23
      DO 16 I=1,50
      SCURR(I)=0.0
   16 CONTINUE
```

```
    9 DO 37 J=1,NTHETA
      THET=THETA(J)
      THETR =THET*0.0174532925
      IF(KINT.EQ.0) GO TO 12
  501 CALL RESPE(THET,TC,AUC,XJLTR,KT)
      GO TO 4
   12 IF(XJLTR.NE.0.0) GO TO 4
    7 JCDREF=IREF/AREA
      XJLTR=JCDREF/140.
    4 JCD=(140.*COS(THETR)/AUC**2)*XJLTR*(1.0&ATX*(TC-TREF))
C        LIGHT GENERATED CURRENT
      IL= AREA*JCD
C        OPEN CIRCUIT VOLTAGE
      VOC = VREF - BRS*(TC-TREF) & VCL(K)*(IL-IREF)
C        SATURATION CURRENT
      IO = IL/(EXP(1.6E-19*VOC/DENOM)-1.0)
C        CURRENT-VOLTAGE CURVES USING DIODE EQUATION
C         CURRENT  (ILOAD) IS IN MILLIAMPS
C         VOLTAGE (VOLTM) IS IN MILLIVOLTS
      VOLTM(1)=0.0
      ILOAD(1)=-IL
      BL=-IL*1.10
      DO 30 I=2,10
      VOLTM(I)=VOLTM(I-1)&10.0
      GS=ILOAD(I-1)
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,E1,E2,NRR)
      GO TO (30,300,300,300,300),NRR
  300 CALL ERROR(300,0)
   30 CONTINUE
      II=0.1*VOC&1.0
      EO=E1
      ET=E2
      DO 301 I=11,II
      L=I-1
      VOLTM(I)=VOLTM(L)&10.0
      CALL TAINT(VOLTM,ILOAD,VOLTM(I),GS,L,2,NRR,DMON)
      IF (GS.LT.BL) GS=BL
      IF(GS.GT.0.0) GS=0.0
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,E1,E2,NRR)
      IF (NRR.NE.4) GO TO 301
      EO=E1
      ET=E2
  302 EO=2.0*EO
      ET=2.0*ET
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,EO,ET,NRR)
```

```
      IF (NRR.EQ.4) GO TO 302
  301 CONTINUE
      II=II&1
      VOLTM(II)=VOC
      ILOAD(II)=0.0
      DO 31 I=1,II
      PILOAD(I)=ILOAD(I) * (-1.0)
   31 CONTINUE
C           DATA OUTPUT FOR EACH THETA
      IF(KOUT.EQ.0) GO TO 33
      CALL PAGE
      WRITE (6,200) R(1),(TITLE(I),I=1,12)
  200 FORMAT(1H ,40X,22HSOLAR CELL PERFORMANCE/48X,A6 ///20X, 12A6//15X,
     126HFIXED CELL CHARACTERISTICS//)
      WRITE (6,201) AREA,VREF,IREF,ATX,BRS,RS
  201 FORMAT(1H ,10X,5HAREA=F6.2,2X,5HVREF=F5.1,2X,5HIREF=F5.2,2X,4HATX=
     1F10.6,2X,4HBRS=F5.2,2X,3HRS=F5.2///11X,48HENVIRONMENTAL CELL PERFO
     2RMANCE  -  (SINGLE CELL)//)
      WRITE (6,202) AUC,THET ,TC,XJLTR,VCL(K),IL,IO,VOC,AA
  202 FORMAT(1H ,10X,3HAU=F5.2,2X,7HTHETA =F5.2,3X,4HTC =F5.1,3X,6HJLTR
     1=,E15.8,3X,5HVCL =F4.2/11X,4HIL =,E15.8,3X,4HIO =,E15.8,3X,5HVOC =
     2,E15.8,3X,3HA =,F5.2///)
      WRITE (6,203)
  203 FORMAT(1H ,25X,1HI,10X,11HCURRENT(MA),10X,11HVOLTAGE(MV)//)
      DO 32 I=1,II
      WRITE (6,204) I,PILOAD(I),VOLTM(I)
  204 FORMAT(1H ,25X,I2, 7X,E15.8, 7X,E15.8)
   32 CONTINUE
   33 IF (NIS .EQ. 0.) GO TO 401
C         CONSTRUCT A STRING I-V ARRAY FOR EACH THETA
      DO 13 I=1,II
      VOLTM(I)=VIS*VOLTM(I)*0.001
      ILOAD(I)= (NIS* ILOAD(I) * 0.001) *  (-1.0)
   13 CONTINUE
C         CURRENT IS NOW IN AMPS
C         VOLTAGE IS NOW IN VOLTS
C
C         CORRECT STRING I-V CURVES - BLOCKING DIODE CORRECTION
C
      DO 15 I=1,II
      VOLTM(I)=VOLTM(I) - SCL
   15 CONTINUE
      SVOLT(1)=0.0
      KSV=0
   27 DO 18 I=1,II
```

```
      IF(SVOLT(I).GT.VOLTM(II)) GO TO 24
   43 CALL TAINT(VOLTM,ILOAD,SVOLT(I),SI,II,2,NER,DMON3)
      IF(NER.NE.1) CALL ERROR(43,0)
      SCURR(I)=SCURR(I) & FTHETA(J)*SI
      FUNC(I)=SCURR(I) * SVOLT(I)
      SVOLT(I&1)=SVOLT(I) & 1.0
      KSV=KSV&1
   18 CONTINUE
   24 IF(J.EQ.1) NSV=KSV
      IF(J.LT.NTHETA) GO TO 37
  401 CONTINUE
      DO 405 I=1,II
      SFUNC(I)= VOLTM(I) * PILOAD(I)
  405 CONTINUE
C
C         POWERMAX COMPUTATIONS
C
      CALL PMAX(PWRMAX,XMAX,FMAX)
C         SPECIFIC POWER
      PSP=PWRMAX/AREA
C         SINGLE CELL CALCULATIONS ONLY
      IF (NIS.NE.0.) GO TO 402
      CALL TAINT(VOLTM,PILOAD,XMAX,SMAX,II,2,NER,DMON5)
      GO TO (404,403,403),NER
  403 CALL ERROR(403,0)
  404 PWRMAX=PWRMAX/1000.
      WRITE (6,205) SMAX,XMAX,PWRMAX
      IF (KPLOT.EQ.0) GO TO 37
      CALL AICRT3(0,0,VOLTM(1),PILOAD(1),II,1,2,1,38,R,ABC ,ORD4,1,1,
     1 16.,16.,1,XL,XU,1,YL,YU)
      CALL AICRT3(0,0,VOLTM(1),SFUNC(1),II,1,2,1,38,R,ABC ,ORD2,1,1,
     1 16.,16.,1,XL,XU,1,YL,YU)
      GO TO 37
C         DATA OUTPUT
  402 CALL PAGE
      WRITE (6,200) R(1),(TITLE(I),I=1,12)
      WRITE (6,211) AREA,VREF,IREF,ATX,BRS,RS
  211 FORMAT(1H ,10X,5HAREA=F6.2,2X,5HVREF=F5.1,2X,5HIREF=F5.2,2X,4HATX=
     1F10.6,2X,4HBRS=F5.2,2X,3HRS=F5.2///11X,51HENVIRONMENTAL CELL PERFO
     2RMANCE  -  (COMPLETE ARRAY)//)
      WRITE (6,207) AUC,TC
  207 FORMAT(1H ,15X,4HAU =,F10.4,5X,4HTC =,F10.4//)
      WRITE (6,206) NIS,VIS,SCL
  206 FORMAT(1H ,15X,5HNIS =,F6.2,9X,5HVIS =,F6.2,10X,5HSCL =,E15.8//)
      WRITE (6,208) (THETA(I),I=1,NTHETA)
```

```
  208 FORMAT(1H ,15X,9HTHETAS  =,5F10.2)
      WRITE (6,209) (FTHETA(I),I=1,NTHETA)
  209 FORMAT(1H ,15X,9HFTHETAS =,5F10.2)
      WRITE (6,210)
  210 FORMAT(1H0/1H0)
      WRITE (6,213)
  213 FORMAT(1H ,25X,1HI,9X,13HCURRENT(AMP) ,9X,14HVOLTAGE(VOLTS)//)
      DO 21 I=1,NSV
      WRITE (6,204) I,SCURR(I),SVOLT(I)
   21 CONTINUE
   36 CONTINUE
      CALL TAINT(SVOLT,SCURR,XMAX,SMAX,NSV,2,NER,DMON1)
      WRITE (6,205) SMAX,XMAX,PWRMAX
  205 FORMAT(1H0/,1H0, 5X,9HI(PMAX) =,E15.8,5X,9HV(PMAX) =,E15.8,5X,8HP(
     1MAX) =E15.8)
      IF(KPLOT.EQ.0) GO TO 52
C         PLOT CURRENT VS VOLTAGE CURVE
      CALL AICRT3(0,0,SVOLT(1),SCURR(1),NSV,1,2,1,38,R,ABSC,ORD1,1,1,
     116.,16.,1,XL,XU,1,YL,YU)
C          PLOT CURRENT*VOLTAGE  VS  VOLTAGE CURVE
      CALL AICRT3(0,0,SVOLT(1),FUNC(1),NSV,1,2,1,38,R,ABSC,ORD3,1,1,
     116.,16.,1,XL,XU,1,YL,YU)
   37 CONTINUE
   52 CONTINUE
      CALL PAGE
   45 LST=1
      GO TO 1
   50 CALL EOFTV
      CALL EXIT
      END
```

```
C SUBROUTINE RESPE  - INTERPOLATION
      SUBROUTINE RESPE(THET,TC,AUC,FJLTR,KT)
      EQUIVALENCE(FIRST,FIRST)
      FIRST=1.0
      REAL IREF,LSOLAR,LREF
      DIMENSION          XYZ(3),XYZ1(3),XYZ2(3),XYZ3(3),NXYZ(3),NXYZ1(3),
     1          NXYZ2(3),NXYZ3(3),TINV(150),TDINV(150),RINV(150),
     2          RDINV(150),TARG(1260),TDARG(1260),RARG(1260),RDARG(1260),
     3          PARDER(3),WAVE(90),LSOLAR(90),RWAVE(90),LREF(90),
     4          TRANS(90),DTRANS(90),RESP(90),DRESP(90),FACTOR(90)
      COMMON /COM1/AREA,IREF,TREF,INT,INR,INTD,INRD
C SOLAR SPECTRUM
C    CENTER WAVELENGTH OF 0.02 MICRON BANDWIDTH OF ENERGY SOURCE
      DATA WAVE/.31,.33,.35,.37,.39,.41,.43,.45,.47,.49,.51,.53,.55,.57,
     1           .59,.61,.63,.65,.67,.69,.71,.73,.75,.77,.79,.81,.83,.85,
     2           .87,.89,.91,.93,.95,.97,.99,1.02,1.06,1.10,1.14,1.18,
     3           1.22,1.26,1.30/
C    FRACTION OF TOTAL ENERGY IN BANDWIDTH  OF ENERGY SOURCE
C                      (RELATIVE DISTRIBUTION)
      DATA LSOLAR/.0103,.0154,.0167,.0182,.0174,.0267,.0270,.0310,.0310,
     1            .0290,.0280,.0270,.0280,.0270,.0270,.0250,.0240,.0240,
     2            .0220,.0210,.0200,.0190,.0180,.0180,.0160,.0160,.0160,
     3            .0140,.0140,.0140,.0130,.0120,.0110,.0110,.0110,.0210,
     4            .0180,.0170,.0160,.0150,.0140,.0130,.0120/
C    NW IS THE NUMBER OF VOLUES IN THE WAVE AND LSOLAR ARRAYS AND MUST
C                 BE REDEFINED IF THE ARRAY SIZE IS CHANGED
      DATA NW/43/
C    CENTER WAVELENGTH OF 0.02 MICRON BANDWIDTH OF ENERGY SOURCE USED TO
C                 OBTAIN IREF
      DATA RWAVE/0.31,0.33,0.35,0.37,0.39,0.41,0.43,0.45,0.47,0.49,0.51,
     1            0.53,0.55,0.57,0.59,0.61,0.63,0.65,0.67,0.69,0.71,0.73,
     2            0.75,0.77,0.79,0.81,0.83,0.85,0.87,0.89,0.91,0.93,0.95,
     3            0.97,0.99,1.02,1.06,1.10,1.14,1.18,1.22,1.26,1.30/
C    FRACTION OF TOTAL ENERGY IN BANDWIDTH  OF ENERGY SOURCE
C                      (RELATIVE DISTRIBUTION)
      DATA  LREF /.0103,.0154,.0167,.0182,.0174,.0267,.0270,.0310,.0310,
     1            .0290,.0280,.0270,.0280,.0270,.0270,.0250,.0240,.0240,
     2            .0220,.0210,.0200,.0190,.0180,.0180,.0160,.0160,.0160,
     3            .0140,.0140,.0140,.0130,.0120,.0110,.0110,.0110,.0210,
     4            .0180,.0170,.0160,.0150,.0140,.0130,.0120/
C    NP IS THE NUMBER OF VALUES IN THE RWAVE AND LREF ARRAYS AND MUST
C                 BE REDEFINED IF THE ARRAY SIZE IS CHANGED
      DATA  NP/43/
C       TIRR IS TOTAL IRRADIANCE IN MV/SQ.CM. OF SOURCE,LREF, USED TO
C                OBTAIN IREF
```

```
      DATA TIRR/140./
      IF (KT.NE.0) GO TO 19
C          TABLES FOR TRANSMISSION
      IF (INT.EQ.0) GO TO 3
      GO TO (1,2,2),INT
    1 READ (5,100) KWAVE
  100 FORMAT(3I10)
      READ (5,101) (TINV(I),I=1,KWAVE)
  101 FORMAT(8F10.4)
      READ (5,101) (TARG(I),I=1,KWAVE)
      DMON=0.0
      GO TO 3
    2 READ (5,100) KWAVE,KTHET,KTEMP
      K1=KWAVE & KTEMP & KTHET
      READ (5,101) (TINV(I),I=1,K1)
      NW1=KWAVE*KTHET*KTEMP
      READ (5,101) (TARG(I),I=1,NW1)
      NXYZ(1)=KWAVE
      NXYZ(2)=KTHET
      NXYZ(3)=KTEMP
    3 IF (INR.EQ.0) GO TO 6
C          TABLES FOR RESPONSE
      GO TO (4,5,5),INR
    4 READ (5,100) MWAVE
      READ (5,101) (RINV (I),I=1,MWAVE)
      READ (5,101) (RARG (I),I=1,MWAVE)
      DMON2=0.0
      GO TO 6
    5 READ (5,100) MWAVE,MTHET,MTEMP
      K3= MWAVE & MTHET & MTEMP
      READ (5,101) (RINV (I),I=1,K3)
      NW3=MWAVE*MTHET*MTEMP
      READ (5,101) (RARG (I),I=1,NW3)
      NXYZ2(1)=MWAVE
      NXYZ2(2)=MTHET
      NXYZ2(3)=MTEMP
    6 IF (INTD.EQ.0) GO TO 9
      GO TO (7,8,8),INTD
C          TABLES FOR TRANSMISSION DAMAGE
    7 READ (5,100) LWAVE
      READ (5,101) (TDINV(I),I=1,LWAVE)
      READ (5,101) (TDARG(I),I=1,LWAVE)
      DMON1=0.0
      GO TO 9
    8 READ (5,100) LWAVE,LTHET,LAU
```

```
      K2= LWAVE & LTHET & LAU
      READ (5,101) (TDINV(I),I=1,K2)
      NW2=LWAVE*LTHET*LAU
      READ (5,101) (TDARG(I),I=1,NW2)
      NXYZ1(1)=LWAVE
      NXYZ1(2)=LTHET
      NXYZ1(3)=LAU
    9 IF (INRD.EQ.0) GO TO 12
      GO TO (10,11,11),INRD
C             TABLES FOR RESPONSE DAMAGE
   10 READ (5,100) JWAVE
      READ (5,101) (RDINV(I),I=1,JWAVE)
      READ (5,101) (RDARG(I),I=1,JWAVE)
      DMON3=0.0
      GO TO 12
   11 READ (5,100) JWAVE,JTHET,JAU
      K4= JWAVE & JTHET & JAU
      READ (5,101) (RDINV(I),I=1,K4)
      NW4=JWAVE*JTHET*JAU
      READ (5,101) (RDARG(I),I=1,NW4)
      NXYZ3(1)=JWAVE
      NXYZ3(2)=JTHET
      NXYZ3(3)=JAU
   12 IF (FJLTR.EQ.-1.0) GO TO 13
      CONST=FJLTR
      GO TO 19
   13 PJ = IREF/AREA
      PINT = 0.0
      GO TO (14,16,16),INR
   14 DO 15 I=1,NP
      CALL TAINT(RINV, RARG, RWAVE(I),FX,MWAVE,1,NER,DMON2)
      PP = LREF(I)*FX
   15 PINT = PINT & PP
      GO TO 18
   16 XYZ2(2) = 0.0
      XYZ2(3) = TREF
      DO 17 I=1,NP
      XYZ2(1) = RWAVE(I)
      CALL TVIN(RR,XYZ2,RINV, RARG, IERR,NXYZ2,PARDER)
      IF(IERR.NE.1) GO TO 511
      PP = LREF(I)*RR
   17 PINT = PINT & PP
   18 CONST = PJ/(PINT*TIRR)
   19 XYZ(2)=THET
      XYZ(3)=TC
```

```
      XYZ1(2)=THET
      XYZ1(3)=AUC
      XYZ2(2)=THET
      XYZ2(3)=TC
      XYZ3(2)=THET
      XYZ3(3)=AUC
      SUM=0.0
      DO 20 I=1,NW
      IF (INT.GT.0) GO TO 21
      TRANS(I)=1.0
      GO TO 24
   21 GO TO (22,23,23),INT
   22 CALL TAINT(TINV,TARG,WAVE(I),TRANS(I),KWAVE,1,NER,DMON)
      GO TO 24
   23 XYZ(1)=WAVE(I)
      CALL TVIN(TRANS(I),XYZ,TINV,TARG,IERR,NXYZ,PARDER)
      IF(IERR.NE.1) GO TO 511
   24 IF (INR.GT.0) GO TO 25
      RESP(I)=0.0
      GO TO 28
   25 GO TO (26,27,27),INR
   26 CALL TAINT(RINV,RARG,WAVE(I),RESP(I),MWAVE,1,NER,DMON2)
      GO TO 28
   27 XYZ2(1)=WAVE(I)
      CALL TVIN(RESP(I),XYZ2,RINV,RARG,IERR,NXYZ2,PARDER)
      IF(IERR.NE.1) GO TO 511
   28 IF (INTD.GT.0) GO TO 29
      DTRANS(I)=0.0
      GO TO 32
   29 GO TO (30,31,31),INTD
   30 CALL TAINT(TDINV,TDARG,WAVE(I),DTRANS(I),LWAVE,1,NER,DMON1)
      GO TO 32
   31 XYZ1(1)=WAVE(I)
      CALL TVIN(DTRANS(I),XYZ1,TDINV,TDARG,IERR,NXYZ1,PARDER)
      IF(IERR.NE.1) GO TO 511
   32 IF (INRD.GT.0) GO TO 33
      DRESP(I)=0.0
      GO TO 36
   33 GO TO (34,35,35),INRD
   34 CALL TAINT(RDINV,RDARG,WAVE(I),DRESP(I),JWAVE,1,NER,DMON3)
      GO TO 36
   35 XYZ3(1)=WAVE(I)
      CALL TVIN(DRESP(I),XYZ3,RDINV,RDARG,IERR,NXYZ3,PARDER)
   36 FACTOR(I)=LSCLAR(I)*(TRANS(I)-DTRANS(I))*(RESP(I)-DRESP(I))
   20 SUM=SUM&FACTOR(I)
```

```
      FJLTR=SUM*CONST
      IF (KT.NE.0) RETURN
      WRITE (6,200) CONST
  200 FORMAT(//// 11X,37HABSOLUTE RESPONSE/RELATIVE RESPONSE =,F10.5)
      KT=1
      RETURN
  511 IF(IERR.EQ.2) CALL ERROR(511,0)
  512 IF(IERR.EQ.3) CALL ERROR(512,0)
  513 IF(IERR.EQ.4) CALL ERROR(513,0)
  514 IF(IERR.EQ.5) CALL ERROR(514,0)
  515 IF(IERR.EQ.6) CALL ERROR(515,0)
  516 IF(IERR.EQ.7) CALL ERROR(516,0)
      END
```

```
      SUBROUTINE PMAX(PWRMAX,XMAX,FMAX)
      EQUIVALENCE(FIRST,FIRST)
      FIRST=1.0
      REAL NIS
      REAL JCD,IL,IO,ILOAD
      COMMON/COM/VOLTM(95),K,RS,DENOM,IO,IL,C7,II,FUNC(50),SVOLT(50),NSV
     1,DMON4,NIS,SFUNC(95),DMON6
      XMAX=0.0
      IF (NIS.EQ.0.) GO TO 25
      DO 10 I=2,NSV
      IF(ABS(FUNC(I)).LT.ABS(FUNC(I&1))) GO TO 10
      N=I
      GO TO 20
   10 CONTINUE
   20 SEC1=0.5*(SVOLT(N) & SVOLT(N&1)) * FUNC(N-1)
      SEC2=(SVOLT(N-1) & SVOLT(N&1)) * FUNC(N)
      SEC3=0.5*(SVOLT(N-1) & SVOLT(N)) * FUNC(N&1)
      A= SEC1 - SEC2 & SEC3
      B=0.5*FUNC(N-1) - FUNC(N) & 0.5*FUNC(N&1)
      XMAX=0.5*(A/B)
      CALL TAINT(SVOLT,FUNC,XMAX,FMAX,NSV,2,NER,DMON4)
      GO TO 28
   25 DO 26 I=2,II
      IF(ABS(SFUNC(I)).LT.ABS(SFUNC(I&1))) GO TO 26
      N=I
      GO TO 27
   26 CONTINUE
   27 SEC1=0.5*(VOLTM(N) & VOLTM(N&1))*SFUNC(N-1)
      SEC2=(VOLTM(N-1) & VOLTM(N&1)) * SFUNC(N)
      SEC3=0.5*(VOLTM(N-1) & VOLTM(N)) * SFUNC(N&1)
      A= SEC1 - SEC2 & SEC3
      B=0.5*SFUNC(N-1) - SFUNC(N) & 0.5*SFUNC(N&1)
      XMAX=0.5*(A/B)
      CALL TAINT(VOLTM,SFUNC,XMAX,FMAX,II,2,NER,DMON6)
   28 IF(NER.NE.1) GO TO 30
      PWRMAX=FMAX
      LAST=1
      RETURN
   30 WRITE (6,200) NER
  200 FORMAT(1H0,12HTAINT ERROR=,I2)
      CALL EXIT
      END
```

```
      FUNCTION FUNL(X)
      FIRST=1.0
      REAL ILOAD,IO,IL,ILSAVE
      REAL NIS
      COMMON/COM/VOLTM(95),I,RS,DENOM,IO,IL,C7,II,FUNC(50),SVOLT(50),NSV
     1,DMON4,NIS,SFUNC(95),DMON6
      C3=1.6E-19*(VOLTM(I)-X*RS)
      C4=C3/DENOM
      C5=IO*(EXP(C4)-1.0)
      FUNL=C5-IL-X
      XX=X
      DUM=FUNL
   10 LAST=1
      RETURN
      END
```

```
C         SOLAR CELL PERFORMANCE PROGRAM - KIRKPATRICK
C
C         GENERAL PURPOSE
C
      EXTERNAL FUNL
      REAL NIS,ISC,IREF,JCDREF
      REAL JCD,IL,IO,ILOAD
      COMMON/COM/VOLTM(95),I,RS,DENOM,IO,IL,C7,II,FUNC(50),SVOLT(50),NSV
     1,DMON4,NIS,SFUNC(95),DMON6
      COMMON/COM1/AREA,IREF,TREF,INT,INR,INTD,INRD
      DIMENSION THETA(10),AU(10),T(10),R(12),ABSC(13),ORD1(13),ORD2(13),
     1ORD3(13),ORD4(13),ABC(13)
      DIMENSION  PVOLTM(95),ILOAD(95),PILOAD(95),A(15),SCURR(50),
     1VCL(10),FTHETA(10),TITLE(18)
      EQUIVALENCE (VOLTM(1),PVOLTM(1))
      DATA R(4),R(7),R(10),R(11)/4HAU= ,4HT = ,4HTHET,4HA = /
      DATA R(3),R(6),R(9)/4H    ,4H    ,4H    /
      DATA ABSC/4H    ,4H    ,4H    ,4H    ,4HVOLT,4HAGE ,4H (VO,4HLTS),
     14H    ,4H    ,4H    ,4H    ,4H    /
      DATA ABC/4H    ,4H    ,4H    ,4H    ,4H VOL,4HTAGE,4H (MI,4HLLIV,4
     1HOLTS,4H)    ,4H    ,4H    ,4H    /
      DATA ORD1/4H    ,4H    ,4H    ,4H    ,4H    ,4H   C,4HURRE,4HNT(A,
     14HMPS),4H    ,4H    ,4H    ,4H    /
      DATA ORD2/4H    ,4H    ,4H    ,4H    ,4H POW,4HER  ,4H(MIC,4HROWA,
     14HTTS),4H    ,4H    ,4H    ,4H    /
      DATA ORD3/4H    ,4H    ,4H    ,4H    ,4H    ,4HPOWE,4HR (W,4HATTS,
     14H)   ,4H    ,4H    ,4H    ,4H    /
      DATA ORD4/4H    ,4H    ,4H    ,4H    ,4H    ,4H  CU,4HRREN,4HT (M,
     14HILLI,4HAMPS,4H)    ,4H    ,4H    /
      DATA E1,E2,BU/0.01,0.0001,0.0/
    1 READ (5,100,END=5000) R(1),R(2)
  100 FORMAT(2A4)
      READ (5,101) (TITLE(I),I=1,18)
  101 FORMAT(18A4)
C
C          KPLOT = 0  SKIP PLOTTING
C          KPLOT = 1  PLOT
C          KOUT = 0  SKIP  DETAILED OUTPUT FOR CURRENT VS VOLTAGE (THETA)
C          KOUT = 1  PRINT DETAILED OUTPUT FOR CURRENT VS VOLTAGE (THETA)
      READ (5,103) NAU,NTHETA,KPLOT,KOUT,INT,INR,INTD,INRD
  103 FORMAT(8I10)
      READ (5,102) (AU(I),I=1,NAU)
      READ (5,102) (T(I),I=1,NAU)
      READ (5,102)  (A(I),I=1,NAU)
      READ (5,102) (VCL(I),I=1,NAU)
```

```
      READ (5,102) AREA,TREF,VREF,IREF,XJLTR,ATX,BRS,RS
      READ (5,102) (THETA(I),I=1,NTHETA)
      READ (5,102)(FTHETA(I),I=1,NTHETA)
      READ (5,102) NIS,VIS,SCL
  102 FORMAT(8F10.4)
      IF(KPLOT.EQ.0)  GO TO 2
      CALL READIN
    2 WRITE (6,221) R(1),R(2),(TITLE(I),I=1,18)
  221 FORMAT(1H1,10HINPUT DATA,5X,2A4,18A4///)
      WRITE (6,220) NAU,NTHETA,KPLOT,KOUT,AREA,TREF,VREF,IREF,
     1XJLTR,ATX,BRS,RS
  220 FORMAT(1H ,10X,7H   NAU=I3/11X,7HNTHETA=,I3/11X,7H KPLOT=,I3/
     111X,7H  KOUT=,I3/       11X,7H  AREA=,E15.8
     2    /11X,7H  TREF=,E15.8/11X,7H  VREF=,E15.8/11X,7H  IREF=,E15.8/
     3  11X,7H XJLTR=,E15.8/11X,7H   ATX=,E15.8/11X,7H   BRS=,E15.8/11X,
     47H    RS=,E15.8)
    5 DMON=0.0
      DMON1=0.0
      DMON2=0.0
      DMON3=0.0
      DMON4=0.0
      DMON5=0.0
      DMON6=0.0
      PI=3.1415927
      KT=0
      KINT = INT & INR & INTD & INRD
      DO 52 K=1,NAU
    6 AUC=AU(K)
      CALL CVRT(AUC,1,6H(F4.2),R(5),1,4H(A4))
   11 TC=T(K)
      AA = A(K)
      CALL CVRT(TC,1,6H(F4.0),R(8),1,4H(A4))
      DENOM=1000.*AA*TC*1.38E-23
      DO 16 I=1,50
      SCURR(I)=0.0
   16 CONTINUE
    9 DO 37 J=1,NTHETA
      THET=THETA(J)
      CALL CVRT(THET,1,8H(F4.1)   ,R(12),1,4H(A4))
      THETR =THET*0.0174532925
      IF(KINT.EQ.0) GO TO 12
  501 CALL RESPE(THET,TC,AUC,XJLTR,KT)
      GO TO 4
   12 IF(XJLTR.NE.0.0) GO TO 4
    7 JCDREF=IREF/AREA
```

```
      XJLTR=JCDREF/140.
    4 JCD=(140.*COS(THETR)/AUC**2)*XJLTR*(1.0&ATX*(TC-TREF))
C          LIGHT GENERATED CURRENT
      IL= AREA*JCD
C          OPEN CIRCUIT VOLTAGE
      VOC = VREF - BRS*(TC-TREF) & VCL(K)*(IL-IREF)
C          SATURATION CURRENT
      IO = IL/(EXP(1.6E-19*VOC/DENOM)-1.0)
C          CURRENT-VOLTAGE CURVES USING DIODE EQUATION
C           CURRENT  (ILOAD) IS IN MILLIAMPS
C           VOLTAGE (VOLTM) IS IN MILLIVOLTS
      VOLTM(1)=0.0
      ILOAD(1)=-IL
      BL=-IL*1.10
      DO 30 I=2,10
      VOLTM(I)=VOLTM(I-1)&10.0
      GS=ILOAD(I-1)
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,E1,E2,NRR)
      GO TO (30,300,300,300,300),NRR
  300 CALL ERROR(300,0)
   30 CONTINUE
      II=0.1*VOC&1.0
      EO=E1
      ET=E2
      DO 301 I=11,II
      L=I-1
      VOLTM(I)=VOLTM(L)&10.0
      CALL TAINT(VOLTM,ILOAD,VOLTM(I),GS,L,2,NRR,DMON)
      IF (GS.LT.BL) GS=BL
      IF(GS.GT.0.0) GS=0.0
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,E1,E2,NRR)
      IF (NRR.NE.4) GO TO 301
      EO=E1
      ET=E2
  302 EO=2.0*EO
      ET=2.0*ET
      CALL ROOT(FUNL,ILOAD(I),GS,BL,BU,EO,ET,NRR)
      IF (NRR.EQ.4) GO TO 302
  301 CONTINUE
      II=II&1
      VOLTM(II)=VOC
      ILOAD(II)=0.0
      DO 31 I=1,II
      PILOAD(I)=ILOAD(I) * (-1.0)
   31 CONTINUE
```

```
C          DATA OUTPUT FOR EACH THETA
      IF(KOUT.EQ.0) GO TO 33
      CALL PAGE
      WRITE (6,200) R(1),R(2),(TITLE(I),I=1,18)
  200 FORMAT(1H ,40X,22HSOLAR CELL PERFORMANCE/48X,2A4///20X, 18A4//15X,
     126HFIXED CELL CHARACTERISTICS//)
      WRITE (6,201) AREA,VREF,IREF,ATX,BRS,RS
  201 FORMAT(1H ,10X,5HAREA=F6.2,2X,5HVREF=F5.1,2X,5HIREF=F5.2,2X,4HATX=
     1F10.6,2X,4HBRS=F5.2,2X,3HRS=F5.2///11X,48HENVIRONMENTAL CELL PERFO
     2RMANCE  -  (SINGLE CELL)//)
      WRITE (6,202) AUC,THET ,TC,XJLTR,VCL(K),IL,IO,VOC,AA
  202 FORMAT(1H ,10X,3HAU=F5.2,2X,7HTHETA =F5.2,3X,4HTC =F5.1,3X,6HJLTR
     1=,E15.8,3X,5HVCL =F4.2/11X,4HIL =,E15.8,3X,4HIO =,E15.8,3X,5HVOC =
     2,E15.8,3X,3HA =,F5.2///)
      WRITE (6,203)
  203 FORMAT(1H ,25X,1HI,10X,11HCURRENT(MA),10X,11HVOLTAGE(MV)//)
      DO 32 I=1,II
      WRITE (6,204) I,PILOAD(I),VOLTM(I)
  204 FORMAT(1H ,25X,I2, 7X,E15.8, 7X,E15.8)
   32 CONTINUE
   33 IF (NIS .EQ. 0.) GO TO 401
C         CONSTRUCT A STRING I-V ARRAY FOR EACH THETA
      DO 13 I=1,II
      VOLTM(I)=VIS*VOLTM(I)*0.001
      ILOAD(I)= (NIS* ILOAD(I) * 0.001) *  (-1.0)
   13 CONTINUE
C         CURRENT IS NOW IN AMPS
C         VOLTAGE IS NOW IN VOLTS
C
C         CORRECT STRING I-V CURVES - BLOCKING DIODE CORRECTION
C
      DO 15 I=1,II
      VOLTM(I)=VOLTM(I) - SCL
   15 CONTINUE
      SVOLT(1)=0.0
      KSV=0
   27 DO 18 I=1,II
      IF(SVOLT(I).GT.VOLTM(II)) GO TO 24
   43 CALL TAINT(VOLTM,ILOAD,SVOLT(I),SI,II,2,NER,DMON3)
      IF(NER.NE.1) CALL ERROR(43,0)
      SCURR(I)=SCURR(I) & FTHETA(J)*SI
      FUNC(I)=SCURR(I) * SVOLT(I)
      SVOLT(I&1)=SVOLT(I) & 1.0
      KSV=KSV&1
   18 CONTINUE
```

```
   24 IF(J.EQ.1) NSV=KSV
      IF(J.LT.NTHETA) GO TO 37
  401 CONTINUE
      DO 405 I=1,II
      SFUNC(I)= VOLTM(I) * PILOAD(I)
  405 CONTINUE
C
C           POWERMAX COMPUTATIONS
C
      CALL PMAX(PWRMAX,XMAX,FMAX)
C           SPECIFIC POWER
      PSP=PWRMAX/AREA
C           SINGLE CELL CALCULATIONS ONLY
      IF (NIS.NE.0.) GO TO 402
      CALL TAINT(VOLTM,PILOAD,XMAX,SMAX,II,2,NER,DMON5)
      GO TO (404,403,403),NER
  403 CALL ERROR(403,0)
  404 PWRMAX=PWRMAX/1000.
      WRITE (6,205) SMAX,XMAX,PWRMAX
      IF (KPLOT.EQ.0) GO TO 37
      CALL AICRT3(0,0,VOLTM(1),PILOAD(1),II,1,2,1,38,R,ABC ,ORD4,1,1,
     1 16.,16.,1,XL,XU,1,YL,YU)
      CALL AICRT3(0,0,VOLTM(1),SFUNC(1),II,1,2,1,38,R,ABC ,ORD2,1,1,
     1 16.,16.,1,XL,XU,1,YL,YU)
      GO TO 37
C           DATA OUTPUT
  402 CALL PAGE
      WRITE (6,200) R(1),R(2),(TITLE(I),I=1,18)
      WRITE (6,211) AREA,VREF,IREF,ATX,BRS,RS
  211 FORMAT(1H ,10X,5HAREA=F6.2,2X,5HVREF=F5.1,2X,5HIREF=F5.2,2X,4HATX=
     1F10.6,2X,4HBRS=F5.2,2X,3HRS=F5.2///11X,51HENVIRONMENTAL CELL PERFO
     2RMANCE  -  (COMPLETE ARRAY)//)
      WRITE (6,207) AUC,TC
  207 FORMAT(1H ,15X,4HAU =,F10.4,5X,4HTC =,F10.4//)
      WRITE (6,206) NIS,VIS,SCL
  206 FORMAT(1H ,15X,5HNIS =,F6.2,9X,5HVIS =,F6.2,10X,5HSCL =,E15.8//)
      WRITE (6,208) (THETA(I),I=1,NTHETA)
  208 FORMAT(1H ,15X,9HTHETAS  =,5F10.2)
      WRITE (6,209) (FTHETA(I),I=1,NTHETA)
  209 FORMAT(1H ,15X,9HFTHETAS =,5F10.2)
      WRITE (6,210)
  210 FORMAT(1H0/1H0)
      WRITE (6,213)
  213 FORMAT(1H ,25X,1HI,9X,13HCURRENT(AMPS),9X,14HVOLTAGE(VOLTS)//)
      DO 21 I=1,NSV
```

```
      WRITE (6,204) I,SCURR(I),SVOLT(I)
   21 CONTINUE
   36 CONTINUE
      CALL TAINT(SVOLT,SCURR,XMAX,SMAX,NSV,2,NER,DMON1)
      WRITE (6,205) SMAX,XMAX,PWRMAX
  205 FORMAT(1H0/,1H0, 5X,9HI(PMAX) =,E15.8,5X,9HV(PMAX) =,E15.8,5X,8HP(
     1MAX) =E15.8)
      IF(KPLOT.EQ.0) GO TO 52
C          PLOT CURRENT VS VOLTAGE CURVE
      CALL AICRT3(0,0,SVOLT(1),SCURR(1),NSV,1,2,1,38,R,ABSC,ORD1,1,1,
     116.,16.,1,XL,XU,1,YL,YU)
C            PLOT CURRENT*VOLTAGE  VS  VOLTAGE CURVE
      CALL AICRT3(0,0,SVOLT(1),FUNC(1),NSV,1,2,1,38,R,ABSC,ORD3,1,1,
     116.,16.,1,XL,XU,1,YL,YU)
   37 CONTINUE
   52 CONTINUE
      CALL PAGE
   45 GO TO 1
 5000 CALL EOFTV
      STOP
      END
```

APPENDIX G

DESCRIPTION OF LIBRARY SUBROUTINES

IDENTIFICATION

AL TVIN, trivariate table look-up
FORTRAN IV, MAP-coded
Ames modification of SHARE library routine SC TRIV

PURPOSE

This subroutine is used to evaluate the function $W = f(X,Y,Z)$, and the partial derivatives $\partial W/\partial X$, $\partial W/\partial Y$, $\partial W/\partial Z$, by linear interpolation, where W is given as a tabulated function of X, Y, and Z.

USAGE

This subroutine is called by use of the statement

CALL TVIN(W, XYZ, XTAB, WTAB, IERR, NXYZ, PARDER)

where

W contains the result of the table look-up

XYZ is an array that contains the arguments for table look-up

XYZ(1) contains X
XYZ(2) contains Y
XYZ(3) contains Z

XTAB is an array that contains the tables of X, Y, and Z values upon which the search is to be made:

XTAB(1) - XTAB(NX) contains the values for $X_1, X_2, \ldots, X_{NX}$
XTAB(NX + 1) - XTAB(NX + NY) contains the values for $Y_1, Y_2, \ldots, Y_{NY}$
XTAB(NX + NY + 1) - XTAB(NX + NY + NZ) contains the values for $Z_1, Z_2, \ldots, Z_{NZ}$

WTAB is an array that contains functional values:

WTAB(1) - WTAB(NX) contains $W(X_1,Y_1,Z_1)$ - $W(X_{NX},Y_1,Z_1)$
WTAB(NX + 1) - WTAB(2*NX) contains $W(X_1,Y_2,Z_1)$ - $W(X_{NX},Y_2,Z_1)$ and so forth, with Z varying last, until
WTAB(NX*NY*NZ) contains $W(X_{NX},Y_{NY},Z_{NZ})$

IERR is an error return code such that

IERR = 1, normal return
= 2, X is too small
= 3, X is too large
= 4, Y is too small
= 5, Y is too large
= 6, Z is too small
= 7, Z is too large

NXYZ is an array that contains the number of variables in XTAB:

NXYZ(1) contains NX
NXYZ(2) contains NY
NXYZ(3) contains NZ

PARDER is an array that contains the partial derivatives:

PARDER(1) contains $\partial W/\partial X$
PARDER(2) contains $\partial W/\partial Y$
PARDER(3) contains $\partial W/\partial Z$

RESTRICTION

The values entered in the three tables in XTAB must increase monotonically.

COMMENTS

This subroutine performs the same function as the subroutine AL TRIV, which is also a modification of SC TRIV. The present version is more convenient to use, however, as tables are loaded in forward order rather than reverse order.

METHOD

The following interpolation formulas are used:

$$X,Y,Z) = W_c + \frac{\partial W}{\partial X}(X - X_c) + \frac{\partial W}{\partial Y}(Y - Y_c) + \frac{\partial W}{\partial Z}(Z - Z_c)$$

$$W_c = f(X_c, Y_c, Z_c)$$

$$\frac{\partial W}{\partial X} = \frac{W(X_{i+1}, Y_c, Z_c) - W(X_i, Y_c, Z_c)}{X_{i+1} - X_i}, \qquad X_i \le X \le X_{i+1}$$

$$\frac{\partial W}{\partial Y} = \frac{W(X_c, Y_{i+1}, Z_c) - W(X_c, Y_i, Z_c)}{Y_{i+1} - Y_i}, \qquad Y_i \le Y \le Y_{i+1}$$

$$\frac{\partial W}{\partial Z} = \frac{W(X_c, Y_c, Z_{i+1}) - W(X_c, Y_c, Z_i)}{Z_{i+1} - Z_i}, \qquad Z_i \le Z \le Z_{i+1}$$

The quantity X_c is X_i or X_{i+1}, whichever is closer to X. If X is halfway between X_i and X_{i+1}, then X_{i+1} is used as X_c. If X = XTAB(NX), for example, the last entry in the table, then X_{i+1} is XTAB(NX) and X_i is XTAB(NX - 1). The above discussion applies for Y_c and Z_c also.

IDENTIFICATION

AL TAIN(TAINT), table look-up and interpolation
FORTRAN IV, MAP-CODED
Written by V. L. Sorensen

PURPOSE

This subroutine is used to evaluate one or more functions of an argument X, when the functions and the argument are given in tabular form.

USAGE

The CALL statement for the IBM 7040/7094 DCS for this subroutine is

CALL TAINT(XTAB, FTAB, X, FX, N, K, NER, DMON, GTAB, GX, HTAB, HX, . . .)

and the CALL statement for the IBM 360/67 is

CALL TAINT(XTAB, FTAB, X, FX, N, K, NER, DMØN)

where

XTAB	is the name of the array that contains the values of the argument of the functions, which must increase or decrease monotonically
FTAB GTAB HTAB . . .	are the names of arrays that contain the values of the functions of the argument in XTAB
X	is the value of the argument for which function values are sought
FX GX HX . . .	are the values of the functions as obtained by the subroutine
N	is the number of tabulated values, and so the arrays XTAB, FTAB, . . . , are of dimensions at least N; $N \geqslant K$
K	is the order of interpolation; $K \leqslant 9$
NER	is an error code: NER = 1, normal return NER = 2, $K > 9$ or $N \leqslant K$ NER = 3, adjacent values within the array XTAB are equal
DMON	is a variable that must be set to zero initially, and whenever XTAB is altered. Each XTAB within a given program should be assigned a unique DMON symbol. The contents of DMON are altered by the subroutine.

RESTRICTIONS

The table XTAB must be monotonic, and adjacent values may not be equal. The order K must be smaller than or equal to 9, and N must be greater than K.

METHOD

A binary search is used to find the region of the table where the desired result is to be found. Aitken's method of interpolation is then used to determine the precise functional values corresponding to the given value of the independent variable. Aitken's method is a computational

scheme for evaluating the Lagrangian interpolation polynomial without having to compute polynomial coefficients. The development of the Lagrangian interpolation method will be omitted here, as details may be found in many standard texts (i.e., see ref. 1). The Aitken method (see ref. 2) consists in the repetitive use of the formula

$$Y^{n}_{m+n} = \frac{Y^{n-1}_{n-1}(X_{m+n} - X) - Y^{n-1}_{m+n}(X_{n-1} - X)}{X_{m+n} - X_{n-1}}$$

The superscripts and subscripts are indices, and never exponents, in this formula. For a given value of the order K, the above formula is applied for n in the range 1, 2, . . ., K, and, for each n, the values for m are taken in the order 0, 1, . . ., K-1. The restriction $n + m \geqslant K$ applies. Thus, for linear interpolation ($K = 1$), this process is carried out with a single application of the above general formula, for example,

$$Y^{1}_{1} = \frac{Y^{0}_{0}(X_{1} - X) - Y^{0}_{1}(X_{0} - X)}{X_{1} - X_{0}}$$

For the case $K = 3$, the process is repeated six times. The six iterations give

$$Y^{1}_{1} = \frac{Y^{0}_{0}(X_{1} - X) - Y^{0}_{1}(X_{0} - X)}{X_{1} - X_{0}} \qquad n = 1,\ m = 0$$

$$Y^{1}_{2} = \frac{Y^{0}_{0}(X_{2} - X) - Y^{0}_{2}(X_{0} - X)}{X_{2} - X_{0}} \qquad n = 1,\ m = 1$$

$$Y^{1}_{3} = \frac{Y^{0}_{0}(X_{3} - X) - Y^{0}_{3}(X_{0} - X)}{X_{3} - X_{0}} \qquad n = 1,\ m = 2$$

$$Y^{2}_{2} = \frac{Y^{1}_{1}(X_{2} - X) - Y^{1}_{2}(X_{1} - X)}{X_{2} - X_{1}} \qquad n = 2,\ m = 0$$

$$Y^{2}_{3} = \frac{Y^{1}_{1}(X_{3} - X) - Y^{1}_{3}(X_{1} - X)}{X_{3} - X_{1}} \qquad n = 2,\ m = 1$$

$$Y^{3}_{3} = \frac{Y^{2}_{2}(X_{3} - X) - Y^{2}_{3}(X_{2} - X)}{X_{3} - X_{2}} \qquad n = 3,\ m = 0$$

Note that the fourth and fifth iterations depend on the first, second, and third, and that the sixth and final one depends on the fourth and fifth. It is evident that the Aitken method may be characterized as the repetitive application of a linear interpolation process.

IDENTIFICATION

AL SC42, S-C 4020 microfilm recorder plotting package
FORTRAN IV 360/50
Written by North American Aviation, obtained from UAIDE

PURPOSE

AL SC42 is a package of FORTRAN IV subroutines used in preparing input tapes for the S-C 4020 Microfilm Recorder (Plotter) operated by Lockheed Missiles and Space Company, Sunnyvale, California. The S-C 4020 produces plotted and printed output on vellum and/or microfilm. The use of this machine offers great advantages for jobs having large volumes of plotted output.

USAGE

An excellent manual for users of the S-C 4020 is supplied by Lockheed (ref. 1), and copies are available from the Computation Division. Usage described in this manual is for an IBM 7094 computer; however, only a few differences exist for usage with an IBM 360/50. These differences are listed at the end of this write-up.

The Ames user must include the following in his program:

1. CALL READIN *

This statement must appear prior to calling any of the ALSC42 subprograms. He must supply a data card to be read by READIN, containing the following information:

Columns	Item	
1-68	Name of user, mail stop, and any other alphanumeric information	*
69-72	Job ID	*
73-80	Date	*

The information contained on this card is used by ALSC42 for the leading and trailing identification frames. The information in columns 69 through 80 is also used for the ID information in the upper right-hand corner of each frame. The CALL READIN statement also generates the leading identification frame.

2. CALL EØFTV

This statement is used to generate the trailing ID frame on the plot tape followed by an end of file, and also writes on tape 6 the number of frames plotted.

3. Necessary control cards

```
INCLUDE DECKS(ALSC42)                                                        *
//GØ.FT01001 DD UNIT=TAPE, VØLUME=SER=ASSIGN,                          X     *
//               DCB=(DEN=2, TRTCH=C, RECFM=U, BLKSIZE=400),            X     *
//               DUSP=(NEW,KEEP), LABEL=(1, BLP)                       X     *
The storage required by ALSC42 is approximately 45,000 bytes.                *
```

The *'s that appear at the right of the page indicate differences between this write-up and the 7094 write-up of ALSC42.

CURRENT MACHINE TIME RATES

As of this date, machine usage charges for the S-C 4020 Microfilm Plotter are as follows:

(1) $90.00 per elapsed machine hour time plus
(2) (a) 5 cents per frame microfilm (16 mm)
    (b) 25 cents per frame hard copy (vellum)
    (c) 27 cents per frame for combination of hard copy and microfilm
(3) $25.00 minimum charge per job submission shall apply to combined cost elements of (1) and (2) above. Generally, a job submission will include plot tapes from several users.

REFERENCES

North American Aviation, Inc., S-C 4020 Manual.
Lockheed Missiles and Space Co., Sunnyvale, California, December 1965.

ALSC42 PLOTTING PACKAGE FOR 360/50

General Description

The S-C 4020 manual that is distributed describes subroutine usage for the IBM 7094 version of ALSC42. The IBM 360/50 version of ALSC42 provides the user with essentially all the capability described in this manual. The differences between the two versions are listed below.

1. The following routines are no longer available:

CHAINV
CLEANV
DSHLNV, see item 21
ERRLNV
GRAC$
IDFRM, IDFRM., IDFRM$
SCCTAB
SCPØØL
SETFRV
VLAGX
VLAGY

2. No routine may have an optional calling sequence of different length than the normal calling sequence. When this restriction appeared to decrease capability, it was circumvented by adding a new routine using the optional calling sequence (see PRINTV and TYPEV).

3. No routine may pass locations of variables instead of values (see SCERRV, SERSAV, SERREV). No capability is apparently lost by this restriction, although the usage of the three routines mentioned is changed somewhat.

4. APLOTV - The characters to be plotted (stored in the array MARKPT) are assumed to be represented by integers (that are right adjusted) if NC is positive, and by characters (that are left adjusted) if NC is negative. Thus, if APLOTV is called with a Hollerith argument for MARKPT, or if MARKPT consists of characters read in with an A1 field, NC must be negative.

5. BNBCDV - The results returned by BNBCDV occupy two words, thus BCDWD must be an array dimensioned at least two. The six characters are right adjusted.

6. EØFTV - No longer rewinds and unloads the plot tape.

7. FRAMEV - Must always be called with an argument.

8. NOFRV - May be called with one argument only

CALL NOFRV(NOFRM).

Returns the current frame count number.

9. POINTV - May be called with three arguments only

CALL POINTV(X,Y, ±NS).

10. PRINTV - May be called with four arguments only

CALL PRINTV(N,BCDTXT,IX,IY).

The "type current point" feature is utilized by a new routine TYPEV that is the same as PRINTV with two arguments.

11. RESETV - May not have an argument. Use FRAMEV if corner marks and frame counting are desired.

12. SCERRV - The arguments represent values of the scaling error indicators instead of locations.

CALL SCERRV(KX,KY).

Stores the current values of these indicators in KX and KY. Thus it is necessary to call SCERRV after using NXV and/or NYV instead of before as described in the manual. See also SERSAV and SERREV below.

13. SERSAV and SERREV - These retrieve and restore the values of the scaling error indicators, respectively. Thus, SCERRV and SERSAV both perform the same function while SERREV allows the programmer to set the indicators to whatever value he desires.

14. TABL-V - Only three tables of vector characters are implemented at the present time - TABL1V, TABL2V, and TABL3V. The structure of vector character tables is somewhat different than described in the manual in that each 12-bit pattern occupies one-half word (16 bits) of the core.

15. XAXISV and YAXISV - May be called with three arguments only

CALL XAXISV(IX,IY,NSTPT).

16. TYPEV - New routine to utilize "type current point" feature of the S-C 4020. Usage is identical to the description in the manual of PRINTV with two arguments

CALL TYPEV(N,BCDTXT).

17. SHFTIV - New routine to perform logical one register, off-the-end shift

CALL SHFTIV(AIN,AOUT,NS).

where

AIN input

AOUT result

NS number of bit positions to shift, left if plus, right if minus

Vacated bit positions are filled with zeros.

18. SHFT2V - New routine to perform logical two register, off-the-end shift

CALL SHFT2V(AIN,BIN,AOUT,BOUT,NS)

Arguments similar to SHFTIV. On a left shift (NS+), bits are shifted through bit position 1 of BIN into bit position 32 of AIN and vice versa for right shift. Vacated positions are filled with zeros.

19. ANDV - New routine to perform logical product of two quantities.

CALL ANDV(A,B,C)

performs C = A * B.

20. ORAV - New routine to perform logical turn of two quantities.

CALL ORAV(A,B,C)

performs C = A + B.

21. DOTLNV, INCRV - New routine for plotting a dashed line.

CALL DOTLNV(IX1,IY1,IX2,IY2)

where

IX1,IY1 start coordinates (integer values)

IX2,IY2 stop coordinates (integer values)

The routine INCRV is used to supply the line and space size. This is set normally at 8 for the line and 4 for the space. These values may be altered, however, by calling INCRV prior to DOTLNV.

CALL INCRV(IL,IS)

where

IL desired length of line in raster units (integer value)

IS desired size of space in raster units (integer value)

If IL and IS are such that the stop coordinates (IX2,IY2) terminate in the space portion of a dash segment, the lost line portion extends to the stop coordinates. Illegal values of IL or IS are ignored by INCRV. DOTLNV will then use the last used values of IL and IS.

IDENTIFICATION

AL AICR, S-C 4020 Microfilm Recorder Plotting Program
FORTRAN IV 360/50
Written by North American Aviation, obtained from Lockheed Missiles and Space Company

PURPOSE

AL AICR is a general purpose subroutine for writing a magnetic tape for displaying graphical output on the S-C 4020. Hard copy and/or microfilm can be obtained. The subroutine will compute scale factors, generate the printing of the scales, generate grid lines and axes, and generate titles and labels from information supplied by the user. It uses the S-C 4020 plotting package (ALSC42) for preparing the magnetic tape that is used as input by the S-C 4020 plotter operated by Lockheed. This plotter offers great advantages for jobs having large volumes of output.

USAGE

This subroutine is entered by the use of the statement:

```
CALL AICRT3(KX,KY,X,Y,NP,ND.NV,NS,NC,T,A,Ø,NF,NG,DCX.DCY,NXØ,XL,XU,NYØ,YL,YU)
```

where

KX 0 for linear display in X, 1 for log display in X

KY 0 for linear display in Y, 1 for log display in Y

X name of the array containing the values of X

Y name of the array containing the values of Y

NP number of points in X and Y array to be plotted

ND interval at which points will be displayed; for example, every point = 1, every tenth point = 10

NV 2 if one wishes to join points plotted with a straight line, 1 for points only

NS 2 if the data are to be sorted as a function of X before plotting (to enable the connecting of points by vectors), 1 if data are not to be sorted

NC decimal equivalent of the character of the point to be plotted (see figs. 1-10 attached), for example, NC = 38 for a circle

T 12-word alphanumeric title to be displayed at the top of the graph (see Special Features) *

A 13-word abscissa title (see Special Features) *

Ø 13-word ordinate title (see Special Features) *

NF 1 if a new frame is required, 2 if overlay is required

NG 1 scale labeling for non-log plots is determined by the magnitude of the numbers. If *any* X meets the following condition: $|X| \geqslant 10^6$ or if *all* X are in the range $-10^5 \leqslant X \leqslant 10^5$, the labeling would automatically be in the E-label notation. 2 non-log labeling is always in the E-label notation.

DCX, DCY } governs the coarseness of the X and Y meshes (see Special Features)

NXØ 2 override search for X-upper and X-lower, 1 let routine determine X-upper and X-lower (see Special Features)

XL X-lower, if needed (NXØ = 2)

XU X-upper, if needed (NXØ = 2)

NYØ 2 override search for Y-upper and Y-lower, 1 let routine determine Y-upper and Y-lower

YL Y-lower, if needed (NYØ = 2)

YU Y-upper, if needed (NYØ = 2)

The Ames user *must* provide the following:

1. CALL READIN *

This statement must appear prior to calling the AL AICR subroutine. He must supply a data card, to be read by READIN, containing the following identification information: *

Columns	Item	
1-68	Name of user, mail stop, and any other alphanumeric information	*
69-72	Job ID	*
73-80	Date	*

The information supplied on the card is used by the S-C 4020 for the leading and trailing identification frames. The information supplied in 69-80 will also appear in the upper right-hand corner of each frame. The CALL READIN statement generates the leading identification frame.

2. CALL EØFTV

This statement is used to generate the trailing identification frame on the plot tape followed by an end of file and also writes on tape 6 the number of frames plotted.

3. Necessary control cards:

```
INCLUDE DECKS(ALSC42,ALAICR)                                                  *
//GØ.FT01F001 DD UNIT=TAPE,VØLUME=SER=ASSIGN,                        X        *
//                DCB=(DEN=2,TRTCH=C,RECFM=U,BLKSIZE=400),           X        *
//                DISP=(NEW,KEEP),LABEL=(1,NL)                                *
The storage required by ALSC42 and AL AIRCR is approximately 51,000 bytes.    *
```

The *'s that appear at the right of the page indicate differences between this write-up and the 7094 write-up of ALAICR.

SPECIAL FEATURES

The recommended value for DCX and DCY is 16.0. If more grid lines are necessary, decrease the values of DCX and DCY. For fewer lines, increase the values of DCX and DCY. The entire array of X and Y being plotted must be in the core when this routine is executed.

The feature of sorting the functions before plotting has one drawback: after the functions have been sorted, the original order is totally destroyed. This feature should not be used unless the plotting of these data is the last function of the code or unless the order of the data is not important.

If $(XU/XL - 1) \leqslant .0001$, or if $XU = XL = 0$, no graph will be drawn as the function is constant or almost constant (similarly for YU and YL).

The titles used should be centered in the 48-character array to insure centering of the titles on the graph. The abscissa and ordinate title can be as large as 52 characters.

If one uses the upper and lower limit search provided by AICRT3, care should be exercised in defining the variable or constant used for XL, XU, YL, or YU as it will be changed by the subroutine.

NG is used to permit a floating point notation labeling of linear plots. This is provided because the maximum fixed point number that can be used is 999999, and the smallest greater than zero is .000001, similarly to negative values. To provide meaningful labeling of data outside this range, the floating point notation has been made available.

The limit of the number of cycles in log plotting is 10. Do not try to plot more than a 10 X 10 log X log plot.

RESTRICTION

This routine should not be used to plot a point at a time.

CURRENT MACHINE TIME RATES

As of this date, machine usage charges for the S-C 4020 Microfilm Plotter are as follows:

(1) \$90.00 per elapsed machine hour time plus
(2) (a) 5 cents per frame microfilm (16 mm)
    (b) 25 cents per frame hard copy (vellum)
    (c) 27 cents per frame for combination of hard copy and microfilm
(3) \$25.00 minimum charge per job submission shall apply to combined costs elements of (1) and (2) above.

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— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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